GEOLOGICAL PAPERS ON WESTERN INDIA,

INCLUDING

CUTCH, SINDE,

AND THE

SOUTH-EAST COAST OF ARABIA;

TO WHICH IS APPENDED

A SUMMARY OF THE GEOLOGY OF INDIA GENERALLY.

EDITED FOR THE GOVERNMENT

BY

HENRY J. CARTER,
ASSISTANT SURGEON, H. C. S., BOMBAY

WITH AN ATLAS OF MAPS AND PLATES.

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PREFACE.

The Right Honorable the Governor, Lord Elphinstone, in Council having considered it desirable that a selection of the papers which had been published on the Geology of the Territories under the Government of Bombay and neighbouring Coast of Arabia should be reprinted, to serve as a kind of "Hand-book" for accelerating the development of the mineral resources of Western India, were pleased to request the Editor, in Mr. Secretary Hart's letter No. 1304, dated 22nd April 1856, to state if he would undertake this duty, forwarding at the same time, and through the same channel, a list of such papers as they deemed necessary for his guidance, with permission to add to or omit from it any that he might think proper.

To this letter the Editor having in reply, intimated his readiness to carry the wishes of the Government into effect, was entrusted with the compilation; and having exercised the discretionary power just mentioned to the best of his judgment, has so far therefore, become responsible for what appears in the following pages.

The plan adopted in the arrangement of the compilation has been, first to introduce the reader to the Geology of the great Trappean Region of Western India, and then to carry him round its outskirts, in order that he might be brought acquainted with the Geological formations of India generally. His attention then is directed to the Geology of Cutch, afterwards to that of Sinde, and, lastly, to that of the neighbouring Coast of Arabia.

For this purpose almost all the Geological Papers that have been written on these different parts have been reprinted *in extenso*, by which the reader will not only have the full advantage of the Authors' descriptions, but the facts contained in them in their own words. Of the papers which have not been printed entire, chiefly to avoid repetition

of what appears in other parts of the volume, abstracts have been made; and of the few which have not been printed at all, whatever they contain worth remembering is embodied in the papers which have been printed *in extenso*. So that with the exception of this matter, altogether only amounting to a few pages, the book comprises all that has been written on the subject, and therefore all that the Geologist of Western India can at present obtain, to lead to future discovery.

It must not be thought, however, that this compilation embraces an introduction to geology; this the reader must have already acquired before he can even understand its contents; nor must the Economist expect to find all that information here which he desires, for such detail would be incompatible with the object of the work; but both will find in it reason based on a geological knowledge of the structure of the earth in India, or, in other words, scientific Indian Geology; a light which, though dim at present, will brighten as it is used, and at length lead to that development of mineral resources which the mere Economist would grope for in the dark, without finding, to the end of time.

All the papers reprinted *in extenso* are unaltered from their original form, with the exception of those by the Rev. Messrs. Hislop and Hunter, and those by the Editor. The former of which have received several valuable alterations and additions from the Rev. Mr. Hislop; and the latter have not only been re-cast in many parts, but have undergone as much alteration, addition, and correction throughout as the Editor had time to give them while they have been rapidly passing through the press.

To the Editor's "Summary of the Geology of India," which was included in the Government list, and has therefore been printed at the end of the volume, the Editor has only been able to add "*Foot-notes*" suggestive of the future alterations that should be made in it; being unable to devote that time to a re-arrangement of the whole which such alterations would necessitate.

Further, that the compilation might be made as useful as possible, not only the maps and plates belonging to most of the papers have been lithographed to accompany them in the form of a separate Atlas, but the Editor has also added an Alphabetical Index for reference to their contents generally.

In the spelling of the names of places the Editor fears that with those who are unaccustomed to the interchange of vowels and permutation of consonants so common in India, an adjustment of the different renderings will be found impracticable ; and he cannot help expressing his regret that any other system of orthography should have ever been introduced for this purpose than that which the mass of educated Englishmen (not *Literati*) would adopt,—that is, spelling the name in English according to its pronunciation in the original tongue. If this had been the case, the greater part of the names of places in this volume would have been alike, instead of different in almost every paper, which, though a matter of little importance to those who have been some years in India, will, he fears, if this paragraph be not read, lead not only to confusion, but a want of confidence in the reprint of these papers, among geologists who are residing in other parts of the world.

Lastly, the Editor would, by way of assurance, observe that in reading this compilation for the purpose of making the Alphabetical Index, he has found the typographical errors so few and of such little importance, that a list of them seems hardly necessary ; but as there are some, and doubtless other defects which he does not at present see, he trusts that the criticisms of the reader will be influenced by remembering, that the compilation has been made, partly written, and partly illustrated in the midst of the performance of harassing and incongruous duties, which not unfrequently, have nearly compelled the Editor to relinquish it altogether.

C.

Bombay, 2nd March 1857.

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GEOLOGICAL PAPERS ON WESTERN INDIA.

On the Fossils of the Eastern Portion of the Great Basaltic District of India. By John G. Malcolmson, Esq., F.G.S.*

[Read November 15th and December 6th, 1837.]

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Introduction.

The principal objects of the following paper are, to submit to the Society an account of a series of fossils discovered in the eastern part of the great basaltic district of India; and to endeavour to arrive at some approximate conclusion respecting the geological era of this basaltic formation, which, extending over more than 200,000 square miles, conceals, breaks up, or alters all the other rocks from beneath which it has forced its way. Of the eruptions to which this rich and romantic country (formerly including several considerable kingdoms) owes its existing form, a late President of this Society remarks† that

* Reprinted from the Transactions of the Geological Society of London, vol. v. p. 537. (Second Series.)

N.B.—In this and the following reprints, copies of the maps only will be now added, and those of the woodcuts and other figures deferred for subsequent publication. Hence there will be a "running number" for the plates which are to contain the latter, substituted for the numbers which appear in the original editions.—Editor.

† See Mr. Murchison's Anniversary Address, Geological Proceedings, vol. i. p. 451.

the mind is almost lost in the contemplation "of their grandeur"; but "that unfortunately the relative age of the eruptions must remain for the present undetermined, no vestiges of secondary or tertiary formations having been detected within the region." Having therefore, in 1832, collected a series of lacustrine fossils, probably referable to the tertiary epoch, from a portion of this district extending 140 miles north and south, and having procured others from localities to the north and west of that which furnished my own collection, I am induced to submit the specimens to the Society.* If they should be deemed of sufficient value, I wish a selection to be deposited in the museum, to afford a means of comparison with a duplicate set, which I shall forward to the Asiatic Society of Bengal.†

But it is not alone by supplying some data from which to infer the relative age of the great trap formation, that these specimens are valuable. They will afford the means of connecting the great sandstone formations of the south and north of India, containing the celebrated diamond mines of Parteal (Golcondah), Bangnapilly, and Panna, as well as the limestones and schists associated with them; and which, from the latitude of Madras to the banks of the Ganges, exhibit the same characters, and are broken up or elevated by granite or trap rocks, in no respect differing in mineralogical characters or geological relations. A few remarks on these formations, and the physical geography of the countries in which they occur, will be a necessary introduction to a more particular account of that portion of the trap district in which the fossils were found, Mr. Calder's sketch not being sufficiently detailed, and the map attached to his memoir containing some errors of material importance.‡

General. Sketch of the Physical Features, Hydrography, &c.

An elevated tract to the north-west of Bundlecund (not included within the range of the Map) may be considered as the geological connexion between the provinces watered by the southern branches of the Ganges and the Deccan, including all the countries to the south of the Nerbudda. From the north of this plateau, which extends far to the west, a number of great rivers descend, by a series of rapids and falls over sandstone escarpments, into the valley of the Jumna and the Ganges. From the east and south of the same tract, the Mahanuddy river collects a great body of water, and after a comparatively short

* See [original] Plate XLVII., [*loc. cit.*—Ed.] drawn, engraved, and described by Mr. James de Carl Sowerby.

† The series of specimens presented by Mr. Malcolmson to the Geological Society have been arranged in the foreign department of the museum.

‡ Asiatic Researches, vol. xviii.

course through countries little known, but containing the diamond mines of Sumblepoor and extensive trap and gneiss formations, empties itself into the Bay of Bengal, not far south of the Delta of the Ganges.

The Nerbudda, which flows in an opposite direction, is more interesting in a political and geological point of view; and the extensive countries through which it passes have been more carefully investigated than any other part of the Peninsula. This river takes its rise to the west of Amerkantack, and traversing a country of granite, sandstone, and basalt, abounding in iron and the finest dolomitic marbles, reaches the Indian Ocean through the alluvial plains of Guzerat. At Jabulpoor and in the neighbourhood of Saugur, fossil mammalia, shells, and silicified palms have been recently discovered. Fossil shells have also been found in some of the trap hills, which have broken up the sandstone near the sources of the Taptee. This river is separated from the Nerbudda by a range of basaltic mountains; and having the same direction as the Nerbudda, its whole course appears to be in the basaltic formation. (See N.W. corner of Map.)

All the other great rivers of the Peninsula, including the Godavery, Kistnah, Pennar, and Cauvary issue from the Western Ghàts, from the summits of which the country slopes gradually to the east, except at the extreme south, where the descent to the plains of the Carnatic is considerable and precipitous.

The Godavery (see Map) rises in the basaltic region described by Colonel Sykes (Geol. Trans. vol. iv. pt. 2, 1836), and, greatly increased in size, it enters the granitic table-land of the Deccan, and flows at the southern foot of the Sichel Mountains into a sandstone and argillaceous limestone country. This district is similar to that of Bundlecund and Malwa; it also contains diamonds, and has been much broken up by erupted rocks. From the north, the Godavery derives large supplies of water from the great rivers rising south of the Nerbudda and the Taptee, in basaltic tracts, the soil of which being retentive of moisture, the water is everywhere near the surface. From the south it receives only the Munjerah river, which, flowing through arid granitic plains, furnishes but a scanty addition of water, except during the rainy season. Through a pass in the gneiss mountain of Papconduh it enters the plains of the Coromandel Coast. In this district the sandstone re-appears, at an elevation little above that of the sea; but basaltic hills, several hundred feet in height, in which marine fossils have recently been discovered, exist almost within the delta formed by its sediment.

The Kistnah derives its waters from a number of considerable rivers, rising in the basaltic and gneiss summits of the Western Ghàts, which condense the greater part of the clouds carried by the south-west monsoon from the Indian Ocean. Flowing through the territories of the

Southern Mahrattas, a country covered with a rich basaltic soil, and abounding in schistose limestone, sandstone, granitic rocks, and basalt, it enters the granitic platform of the Deccan, the limits of which in this direction are unknown. The limestones and sandstones, however, soon re-appear on descending the river, and extend across to the basin of the Pennar, and as far as the ascent to the granitic platform of the Mysore. It is on the banks of the Kistnah that the richest diamond mines occur, and that the sandstones acquire their greatest elevation, amounting to more than 3,000 feet; the river passing through mural precipices of this rock and of the schistose limestones to be presently described. It then enters the plains of the Carnatic, where the same rocks occur, sometimes a little elevated above the level of the sea, at others forming the caps of granite mountains, or broken up by varieties of greenstone and basalt. Thence, passing through a narrow gorge in the gneiss hills of Bezwarrah, it enters the alluvial plains continuous with the delta of the Godavery. Its waters, however, are more loaded with mud than the lastmentioned beautiful river, and the deposit of new land may be seen, by the inspection of a common map, to be proportionably great.

The Pennar is comparatively a small stream, but of much geological interest, the greater part of its waters being derived from the districts in which the diamond sandstones and the argillaceous limestones, on which they rest, are exhibited in their most characteristic forms, and where they are most easily investigated. To describe these strata in detail would be out of place here: but a few of the leading facts must be stated, that the identity of the formations with those of the fossiliferous district, more immediately the object of this paper, may be rendered manifest. Like all the rivers of Southern India, granite is frequently seen in the bed of the Pennar, more especially in its southern branches, where the passes of Ryachottee lead to the granitic table-land of Mysore, having an elevation of 3,000 feet above the sea, or 2,500 above Cuddapah, the principal town of the Pennar basin. With these exceptions, and the occasional appearance of trap through the stratified rocks, the rest of its course, till it approaches the sea, is over rich plains of black and saline alluvium, derived from the decomposition of basalt and of the stratified rocks so often referred to. From these plains numerous table-lands, insulated eminences, and ranges of hills, having for the most part a direction nearly N.E. and S.W., rise abruptly, presenting mural precipices of difficult access, around the base of which the roads often make extensive circuits. The Nulla Mulla hills, extending from the Mysore frontier to the basins of the Kistnah and Godavery, and the minor ranges dependent on them, and having the same composition and direction, are crossed at right angles by the Pennar, which makes its

way through them, like the Kistnah, by traversing narrow gorges with perpendicular sides.

There is not a more remarkable phenomenon in the district watered by the Pennar than the horizontal summits of many of the ranges, and the distinct manner in which the continuity of the strata can be traced from one hill to another, although extensive plains intervene; while, at no great distance, the sandstone which forms the summits of these hills is seen on the same level as the surrounding plains. Numerous instances also occur in which the original continuity of the horizontal summits is easily traced; the strata on the opposite and nearly perpendicular sides of a valley being similar, but having a considerable dip, the beds descend to the general level of the country. A good example of this is seen in Section 2 (Map), at Chintagoouta and Gundicottah. These anomalies were at first quite inexplicable, nothing appearing in the valleys but a rich alluvium, nor on the summits (which are reached with much difficulty) but a sandstone perfectly horizontal, and divided into huge tables by perpendicular partings, sometimes separated several feet from each other, and filled with broken pieces of the rock. This jointed structure is common to the sandstone, the schistose beds on which it for the most part immediately reposes, and the stratified limestone into which these schists pass insensibly; but the size of the tables so formed varies from rhombs of a few inches, in the schist and lower part of the sandstone, to enormous masses on the summits of the hills. Nowhere is this structure and the succession of strata, of which it is characteristic, better seen than in the table-land in which are situated the celebrated diamond mines of Bangnapilly and others now deserted. The accompanying woodcut (Plate I. fig. 1) will give some idea of one of these mines.

The plains at the base of the table-land of Bangnapilly consist of a rich black alluvium, containing fragments of basalt, jasper, and the various minerals found in the hills. It rests on a fine, compact, dark blue or nearly black limestone, which contains much argillaceous and siliceous matter. This limestone abounds with springs, and is in some places so cavernous as to afford passage to subterranean streams. Basalt protrudes in a few places near Bangnapilly. On ascending the hill, the limestone becomes more schistose, and is of a paler colour, gradually approaching in its structure and composition to clay slate, but it is far more friable. On the schist a more or less compact sandstone rests, varying very much in colour, composition, and appearance in different places. Above Bangnapilly it contains the diamond breccia described by Voysey. As far as the shafts which I had an opportunity of observing enabled me to judge, the breccia is not an interstratified rock, but an intermixture of the common sandstone, in different parts of the

same stratum, with larger fragments of older rocks, generally rounded but sometimes angular. It is not, however, the object of this paper to describe the mines and the interesting district in which they occur further than is necessary to exhibit the type of the formation, by the study of which I was enabled to understand more clearly the less distinct appearances exhibited by the same rocks, where they have been invaded or buried by the great basaltic eruptions of Central India. On the opposite or west side of the valley, the hill is composed of the same argillo-calcareous formation; but, according to Colonel Cullen, "instead of a sandstone cap, it is crested in its whole length with a sharp black ridge of trap rock, formed of loose blocks piled upon each other, the apparent base of which observed a pretty uniform level, nor is the ridge of much depth. Its extreme narrowness, deep black colour, and the total absence of all traces of vegetation, formed a singular contrast to the rest of the hills, which were covered with long dry grass and scattered bushes."* At a small pass some miles further to the west, the road in ascending passes over first the dark limestone and a narrow belt of schist, then trap, which is again succeeded by limestone, and the latter by schist, nearly to the summit, "which is capped with a rock of a beautiful flesh colour, with specks and shades of a beautiful green, as if connected with its vicinity to the trap, and of so close and fine a texture as to appear homogeneous even with a lens." "The descent of the pass on the opposite side consists of a clay slate nearly to the foot, where the limestone re-appears, and these two rocks continued to alternate with each other to the foot of the second Ghàt, which, like all the former, was composed of clay slate capped with quartzose sandstone."†

The sandstone exhibits many varieties of grain, colour, and hardness: in some places it is white or red, and can be cut into pillars and slabs of great size and beauty; in others it is soft and friable, and its inferior beds are not unfrequently schistose, so as to be with difficulty distinguished from the subjacent rock, with which it has in one or two places been observed to alternate. Where the sandstone approaches the great granitic tracts to the south and west, it passes into a compact quartzose rock, as is seen on both sides of the Tripatty Valley. This passage is also observed in other places, as near the Cuddapah diamond mines, where the plentiful occurrence of basaltic pebbles shows the neighbourhood of the trap. Besides the diamond conglomerate, consisting of a great variety of minerals, seams of rock crystal occur, and a fine white quartz containing argentiferous galena, which in former

* Colonel Cullen, in Transactions of the Literary Society of Madras, January 1837, p. 50.
† Ibid.

times furnished the country with lead. Specular and micaceous magnetic iron ores, but containing much peroxide, and common iron pyrites, occur with the galena. As far as I have observed, the sandstone always rests conformably on the schists, although from its jointed structure it occasionally, when elevated, appears to meet the subjacent rock at a more or less obtuse angle.

The schists on which the sandstone rests vary very remarkably in colour, being in different places blue, red, green, or pure white, in which they seem to bear some relation to the incumbent sandstone. They are also occasionally flinty or jaspideous. Sometimes they are wanting, the sandstone resting directly on the limestone, of which the schists are evidently merely the upper beds, and into which they pass insensibly, although it seldom happens that considerable effervescence does not occur on examination by tests. It is in many places impossible to say to which portion of the series any particular specimen belongs.

Voysey has classed the schists with the sandstone under the name of "the clay slate formation"; I have, however, preferred to designate the deposit "argillaceous limestone," a term used by him in one of his sections as applicable to the limestone, and which well expresses not only the general character of the rock, but that also of the upper schistose beds.

The limestone is a compact rock, but the strata are usually thin, and are often intersected by vertical partings, a circumstance which frequently limits its use in ornamental architecture. Its most common colour is a light blue, passing into black; but it occasionally occurs of a nearly pure white, and affords an admirable material for basso-relievos. On this stone the finest sculptures of the ruined city of Amrawuty are executed, and for delicacy of workmanship they have perhaps never been surpassed. Were it not for the occurrence of small crystals of quartz, the same quarries would furnish an excellent lithographic stone. Near Cuddapah the dark variety is the common building stone, and many fine columns, caryatides, and cisterns are composed of it. The stone is applied to the same objects in the Southern Mahratta country, and along the course of the Godavery towards Nagpoor.

To the south and east of Cuddapah, a narrow valley, nearly 150 miles in length, extends through the limestone, the strata of which are in some places nearly vertical, but form rounded hills. In others they are capped by sandstone, which exhibits mural precipices of much grandeur, and almost or entirely inaccessible. The strata, for the most part, dip to the N.W., resting on the granite of the Carnatic. This rock is penetrated by many dikes of greenstone, which have evidently

been instrumental in elevating the stratified rocks to their present singular positions. Little has yet been ascertained regarding the thickness of these strata, which differ much even in the same range of hills. The only minerals they have been ascertained to yield are varieties of quartz and iron pyrites, the latter of which is so abundant in a few localities that sulphur is manufactured from it. At Jumulmugadoo I found the limestone interstratified with muriate of soda; and it is therefore probable that the salt diffused through the alluvial soil so extensively as to render the water of the Pennar brackish during the hot season, and the inhabitants independent of the sea-coast for a supply of that article, is derived from this source.

On emerging from the gorge in the Nulla Mulla range the Pennar enters the plains of the Carnatic, and near its mouth flows through low hills of laterite. This deposit rests on the ordinary granite of the Carnatic, with its associated syenites, hornblende schist, quartz rock, and mica slate. It is in a rock composed of a mixture of the last two minerals that the copper-mines of the Nellore district are situated.* In the same neighbourhood, the sandstone and argillaceous limestones are little elevated above the sea, and are continuous with the same rocks on each side of the Kistnah. They are broken through by insulated basaltic hills, in the neighbourhood of which subterranean sounds and frequent local earthquakes are reported to occur; an assertion I am the more inclined to believe, having myself experienced two slight shocks during a casual visit to the district.

Having briefly described some of the more remarkable phenomena exhibited by the southern portion of the great sandstone and argillaceous limestone formations, it will be unnecessary to enter into any detail when we meet with the same rocks to the north of the Godavery in connexion with the fossil beds discovered in the great basaltic district.

Granite Platform between the Kistnah and Godavery.

(See Map and Section 1.)

With regard to the granitic platform of the Deccan, which intervenes between the Kistnah and Godavery, much accurate information is already before the public; it will therefore be necessary only to observe

* The ores are of various kinds, but the richest is a sulphuret, containing, according to Mr. Prinsep, 69 per cent. of the pure metal. The copper also occurs in a slate which Mr. Ouchterlony, of the Madras Engineers, informs me was considered in Cornwall to be identical with the Killas. If this slate belongs to the "argillaceous limestone" formation, the fact will be of use in determining the relations of that rock to the gneiss, talc slate, and mica schist; a subject on which no observations of any value have yet been made. The primary rocks of this district contain magnetic iron ore and corundum, both of which occur in the diamond sandstone.

that it is intersected by numerous greenstone dikes (sometimes of greenstone porphyry), having for the greater part a direction from S. by E. to N. by W., and not very different from that of several of the ranges of basaltic mountains to the north.

These dikes, and the detached masses connected with them, are entirely composed of a crystalline compound of hornblende and felspar, without distinct crystals of augite; and I have never detected olivine in them. The rock shows a tendency to separate into spheres composed of concentric layers and into irregular prisms; and the same structure in some degree occurs in the granite, syenite, pegmatite, &c. of the whole of the south of India. The greenstone is exceedingly hard and difficult to work, but it takes a most beautiful and durable polish, as in the magnificent mausoleums of Golcondah, the tombs of Hyder Ali and Tippoo Sultan, at Seringapatam, and in many of the sculptures of the Carnatic pagodas.* Where these dikes rise into hills, the summits only are composed of the compact greenstone, which graduates below into the granite of the surrounding country. Many of the veins of basalt in the passes of the Mysore and Neilgherry Mountains differ from these, in possessing the structure of the compact basalt of Bombay and other places in the trap countries, and in branching into narrow veins (often not an inch thick), which traverse the granite without mixing with it; while the ordinary greenstone dikes of the Deccan are almost always accompanied by separate nodules, of greater or less dimensions, insulated in the granitic mass, the component parts of which appeared to me to be there, in most cases, arranged in larger crystals, and to be more subject to decay, than in other places. I could not resist the inference, that, at the time of the formation of these dikes, the granite was in a state approaching to fluidity; although, as some of the narrow veins can be traced for many miles through the granite, they do not appear to have been formed at the same time.

Several small basaltic hills are insulated in the granitic platform in the line of route between Hyderabad and Nirmul, and they are based on decaying granite. Their flat summits and steep sides correspond with the hills of the great trap district; and the general line of bearing of the broken ranges of which they appear to form a part does not differ much from that of the basaltic mountains to the north, or from the greenstone dikes; but many hills are scattered over the plains to the east and west, and cross this line of route in every direction. The lower part of the hills is composed of thin tables or laminæ of a sonorous trap, and the upper of globular concentric basalt; the external layers of which are extremely friable, generally grayish, or soft and soapy to the feel, and are of a greenish tint, except where the stone is much loaded

* It is familiarly known in India as "black granite."

with ferruginous grains of a reddish brown colour. In some places the metallic matter has the appearance of having been partially smelted, and is of a fine red hue.

The nuclei of the "concentric basalt," which are exceedingly tough, and resist decomposition powerfully, are of a deep black colour, and contain large crystals of olivine, and small kernels of calcedony. The first of these minerals is not found in the soft external coats, yet it is so closely united with the substance of the rock as not to admit of a doubt of its being of contemporaneous formation, and not, as supposed by Berzelius,* a fragment of a pre-existing stone enveloped in the liquid matter. Small, but very characteristic specimens of calcedony are of more frequent occurrence in the softer portions of the rock, especially between the concentric nodules; but they are intimately mixed with their substance. It is remarkable that I detected no calcareous minerals in similar situations in these hills, although the rock is so impregnated with lime as to have led to an extensive deposit of calc-tuff (Kunkur), at present forming along its base, and projecting sometimes half a foot from between the partings of the basaltic tables. "The presence of olivine, the soft wacké in which the globular basalt is imbedded, the less crystalline structure, the passage into a porous amygdaloid, containing calcedonics, zeolites, &c. and the granite in the neighbourhood of all the smaller masses differing little from that at a distance," may perhaps be sufficient to distinguish these insulated basaltic hills from the greenstone.†

On approaching the Godavery, the granite in some degree changes its appearance, containing large and beautiful crystals of red felspar, occasionally imbedded in veins of transparent quartz, clouded with spots and wavy lines of a turbid milky colour. Greenstone dikes are there more common. The river flows over granite, which is intersected by several dikes of greenstone, running more in a north and south direction than those above referred to, and having many minute white crystals diffused through their substance. The dikes project from 8 to 10 feet above the granite, and are divided into rhomboidal masses by fissures, in which lime is deposited. The bed of the river is covered by numerous fragments of calcedonics, zeolites, and other minerals found in volcanic rocks; and they have been cemented into a more or less solid calcareous conglomerate. The banks are composed of a black basaltic soil; from the lower part of which, where it rests on the granite, as well as from the divisions between the several layers of alluvium, thin slabs of a clayey calc-tuff (Kunkur) project, and are connected above with portions formed round the roots of plants, and below with

* Edinburgh Journal of Science, January 1830.

† Journal of the Asiatic Society of Bengal, February 1836, p. 105.

other layers spread out between the different strata of alluvial earth.* These appearances sufficiently indicate the neighbourhood of the basaltic range of mountains distinguished in Arrowsmith's large map as the Sichel or Shesha hills, but which are locally known by the name of the Nirmul range, from the large town situated six miles from the difficult pass leading up the steep escarpment presented by their southern face. None of the stratified primary rocks are seen at the foot of these hills in the line of the section; but twenty miles to the east of Nirmul, and a few miles south of the mountains, hornblende slate occurs, resting on granite and quartz rock.

Iron Ore, Mines, and Manufacture of the Steel.—The magnetic iron ore, employed for ages in the manufacture of the Damask steel used by the Persians for sword-blades, is obtained from this schist. The mines I examined are those of Deemdoortee, but the ore is extensively distributed. The minute grains or scales of iron are diffused in a sandstone-looking gneiss or micaceous schist, passing by insensible degrees into hornblende slate, and sometimes containing amorphous masses of quartz. The strata are much broken up and elevated, so that the dip and direction are in no two places the same, and bear no relation to the mountains to the north.

Manufacture, &c.—The mines are mere holes dug through the thin granitic soil, and the ore is detached without difficulty by small iron crow-bars. It is then collected and broken on projecting masses of granite or quartz by means of a conical-shaped fragment of compact greenstone; but when too hard to yield to this simple instrument, it is previously roasted. The sand thus procured is washed in shelving depressions dug near a tank, and the heavier parts, separated by this process, are exactly similar to Voysey's specimens of the iron-sand used in the manufacture of Damascus steel at Kona-Sumoondrum, in the same neighbourhood; but from his published papers it does not appear that he had seen the rock from which they were derived. In other respects, all the information I could procure accurately corresponds with that given in his interesting paper.† The ore is then smelted with charcoal in small furnaces, which have often been described. I did not see any flux used; but, although I watched the whole process, from the digging of the ore till it was formed into bars, I will not assert that none was employed. The iron has the remarkable property of being obtained at once in a perfectly tough and malleable state, requiring none of the complicated processes to which English iron must be subjected, pre-

* Further details on this part of the route will be found in some notes explanatory of a collection of specimens presented to the Asiatic Society of Bengal, and published in the Journal of that Institution for February 1836.

† Journal of the Asiatic Society of Bengal, vol. i. p. 245.

vious to its being brought into that state. Mr. Wilkinson, who has investigated the history of Indian steels with much scientific and practical skill, did me the favour to submit to experiment a specimen of this iron as it came from the furnace. He found it to be extremely good and tough, and considered it superior to any English iron, and even to the best descriptions of Swedish. The Persian merchants, who frequent the iron-furnaces of Kona-Sumoondrum, are aware of the superiority of this iron, and informed Dr. Voysey that in Persia they had in vain endeavoured to imitate the steel formed from it; a failure which could be ascribed only to the difference of the materials used, as the whole process of the conversion into steel was conducted under their own superintendence. It is also probable, that there are few places in India where an ore of equal value is so easily procured; otherwise its distant inland situation, in a difficult and unsettled country, would not have retained a reputation for so many ages. In the manufacture of the best steel three-fifths of this iron is used; the other two-fifths being obtained from the Indoor district, where the ore appears to be a peroxide. It is evident, that if the beautiful water of the Damascus blades is derived from the crystallization of the steel, the use of two very different varieties of iron, one of which has been ascertained to be of such admirable quality, must have an important influence on the appearance and quality of the manufacture.

As these mines afford a boundless supply of ore easily wrought, and are situated in the neighbourhood of vast forests, and near a river navigable for boats during part of the year, it is probable that at no distant period, when the native government has undergone some amelioration, iron may become an important article of commerce. On this account, and because, although much has been written regarding Indian steel, nothing has yet been brought prominently forward regarding the finer kinds of iron ore with which that country abounds, I will make a few additional observations regarding them.

Dr. Heyne has accurately described the manufacture of iron in the Carnatic to the south of the Pennar river, and he states that it is, when first smelted, extremely brittle, requiring several operations to bring it into a malleable state. I possess specimens of two varieties of ore used in the district in which he observed the processes, and where I have myself seen them carried on. The one, an iron sand, collected in the beds of rivers, consists of the protoxide, mixed with much of the peroxide; the other, a red schist, is almost entirely composed of red oxide, but in the centre of the mass it affects the magnet. Not far from where this rock occurs, I collected specimens of hornblende schist, leaving little doubt as to the ores being of the same nature, the former having become altered *in situ*, in the same manner as some of the

superficial strata at Deemdoortee are seen to do. I therefore conclude that the superior quality of the Nirmul iron depends on the ore being a comparatively pure protoxide. It certainly is not dependent on the nature of the fuel, which is much the same in both places.* Captain Herbert, indeed, long ago suggested that the superiority of the Gwalior iron ore over that principally worked in the Himalayahs depended on the former being a magnetic ore, like that of Sweden; but the first accurate information on the subject was communicated by Dr. Royle to Mr. De La Beche, who states,† on the authority of that gentleman, that magnetic iron ore is extensively diffused in hornblende slate in the central range of mountains in India, and that it also occurs in the Himalayahs. This geological position corresponds with that of the Nirmul ore; but the latter does not bear any resemblance, except in its peculiar lustre, to the Menaccanite of Cornwall, to which it is compared by Mr. De La Beche; nor could I detect any titanium in it. With regard to the geological relations of the magnetic iron ore, it is also necessary to observe that in India it is not confined to the hornblende schist, but is found extensively distributed in the granite and gneiss of the Carnatic and Mysore, in quartz rock near the iron works of Porto Novo, and, as has already been observed, associated with galena in the diamond sandstone of Cuddapah. The discovery of a mineral, so generally confined to the primary rocks, in the great sandstone formation, affords an additional argument in favour of the opinion of those who consider this rock and the subjacent schists as equivalents to the older European sedimentary formations, rather than to those of the supermedial order.

Description of the Sichel Hills, and of the Freshwater Shells.

Returning to the line of route, the granite, on approaching to the Sichel hills, becomes softer and decomposes rapidly; and the soil gradually changes to the well-known black basaltic mould, known in India by the name of "cotton ground," and, as usual, it is mixed with calcedonies, zeolites, &c. Amongst these minerals were some fragments of a red colour, and considerable specific gravity, though full of irregular cavities, and so like the slag of an iron furnace that I considered them to have had that origin, till I discovered a considerable mass of a similar nature protruding from the granite and black soil by which it was covered. Along with these fragments were others of a semivitrified

* Iron, which has been ascertained to be superior, for many purposes, to the best German iron, has been recently imported from the western coast of India; but the mines from which it was obtained have not been examined. Captain Jervis, of the Bombay Engineers, however, informs me, that ores, powerfully affecting the magnet, exist in great quantity at Taygoor, a village of the Concan, not far from the port from which the iron in question was procured.

† Manual of Geology, 3rd edn., p. 435.

matter, containing small white crystals of felspar, and hardly to be distinguished from a piece of granite fused by Dr. Voysey in the steel furnaces of the neighbouring district. The granite constitutes the surface rock a little further, gradually passing into a black compact basalt intermixed with many white spots, apparently of felspar. The trap then becomes softer, forming small hills of a cellular amygdaloid, abounding in cavities lined with green earth, and many of them filled with calcedonies, zeolites, quartz crystals, and, more rarely, calcareous spar, of the same kind as those, so remarkable for their beauty, in the portion of this formation described by Colonel Sykes (Geological Transactions, vol. iv. p. 422).* The crystals also occur in seams, or are diffused through the trap; and in both cases are intimately mixed with its substance. In the bed of a torrent between two of these hillocks, I met with some soft, clayey, schistose fragments, and others of a siliceous character, and of a black bituminous appearance in the centre, containing very perfect specimens of the *Paludina Deccanensis* (Pl. III. fig. 20), and fragments of other shells to be hereafter described. Those which I examined were converted into calcedony. A laborious research on the hill failed to discover them *in situ;* but about half-way up the escarpment of the principal mountain, which is very steep, and composed of concentric nodular basalt, imbedded in a soft greenish wacké, a narrow band of a singular quartz rock projected about two feet from the surface. It was remarkably scabrous, of various shades of white and red, and had cavities on its surface covered with fine silky crystals. It had every appearance of having been forced into its present situation, when the basalt covered and partially melted the bed to which it belonged.

Many fragments of this rock were found below with the shells; and it was again met with, together with the same and other fossils imbedded in basalt, near Hutnoor. The specific gravity of this rock is 2·473, and some of the specimens effervesced feebly in acids, a portion of lime being dissolved; circumstances in which it corresponds with a similar formation found by Voysey, associated with shells, probably of the same kind, at Medcondah (south of the Godavery), an insulated basaltic hill resting on granite, to which I shall have occasion again to refer. The highest summit of the hills, above the locality of the fossils, is conical, but it is capped by a perfectly horizontal stratified rock, the

* A beautiful variety of chabasie, having the angles replaced by triangular or pentagonal faces supporting a rhomboidal surface, of which beautiful specimens abound in certain localities of the western portion of the formation, has not been met with in this neighbourhood; but, like some other minerals of the basaltic district, it is not generally diffused in the rocks where it is most abundant; so that I have travelled for several hundred miles without meeting with it.

nature of which I could not determine. It is most probably tabular basalt, although that rock is seldom found in similar situations.

Such are the appearances presented on ascending the difficult pass leading up the steep escarpment of the Sichel hills, which form the southern boundary of the eastern portion of the great trap formation of Central India. The hills extend from the junction of the Wurdah and Godavery rivers (the basins of which they separate), till they are lost in the gradual rise of the country to the west, near Lonar (lat. 20° long. 76° 30′), in the province of Aurungabad. Their direction is W.N.W., and, as far as can at present be inferred, they seem to be continuous to the east with numerous ranges of basaltic sandstone, and granitic hills, extending to the Eastern Ghàts, at the lower parts of the course of the Godavery. The extreme breadth of the range, from the foot of the Nirmul pass to the town of Yedlabad (nearly on a level with the plain country of Berar), is about 40 miles ; but several smaller hills, having for the greater part the same direction, are intimately connected with them to the north, as far as the Wurdah river, which has an elevation of little more than 600 feet above the sea. The Sichel hills are arranged in terraces, with steep sides having projecting spurs, and their summits rise occasionally into conical elevations with rounded or flat tops. They inclose narrow valleys abounding in streams, or support table-lands covered with black soil strewed with trap boulders, and having water everywhere near the surface. A thick wood and grass jungle, composed of very different plants from those common on the granite hills, cover the whole tract, with the exception of the flat summits and some of the terraces, and render it unhealthy for the greater part of the year. The basalt of which they are composed is generally globular, the spheroids being sometimes of great size ; but in many of the water-courses, even of the elevated table-lands, it has a stratified appearance. Small basaltic columns are also met with on the crests of some of the spurs and higher ridges ; and where they occur no fossils and few minerals are found. Granite not only forms the base of the hills at Nirmul to the south, and Yedlabad to the north, but part of the mountains themselves, the basalt being seen to rest on decomposing granite about the centre of the range, in a deep ravine, through which the Koorm river passes ; it also again appears high in the table-land to the north of that river, and in one of the terraces of the northern descent, where the most extensive fossil beds were found. Further detail is unnecessary, as Dr. Voysey's admirable description of the Gawilghur mountains, forming the northern boundary of the great and fertile valley of Berar, as these hills do its southern limits, applies equally well to both ranges.*

* Asiatic Researches, vol. xviii.

The fossils were first discovered *in situ* near Munoor, in the basaltic table-land north of the Koorm river; and were subsequently found in the descent of the hills towards Hutnoor, and in different parts of the Mucklegnudy pass, leading into the Berar valley. They consist of numerous gyrogonites; two species of Cypris; two, or perhaps three, species of Unio; and many individuals referable to the genera Paludina, Physa, and Limnea. (Plates II. and III.) The rock in which they occur varies in different places. Some of the finest specimens were procured from a red chert with scabrous surface, having silicified shells distributed throughout its substance, or projecting from its surface. The chert is deeply imbedded in the nodular basalt, from which it projects in some places several feet. The finest specimens of Unio occur in a beautiful gray chert, imbedded in the basalt, or resting immediately on it, the under surface being plain and smooth, while the upper is rough, from portions of the large shells which project from it. On breaking up one of these masses, it was found to contain entire Unios, many of them having the valves connected and closed, or partially open; the interior being filled with the same chert, spotted with fragments of shells, minute univalves, and fine specimens of the two species of Cypris, which occur so abundantly. Some parts of the rock exhibit a mixture of sand, clay, and fragments of shells, of very moderate hardness; but the greater portion consists of chert, the materials of which are occasionally arranged in a beautiful, light blue, enamel-like substance, around irregular cavities containing crystals of purple quartz. Some portions also exhibit a minute vesicular structure; and the whole appearance of this beautiful rock forcibly impresses the mind with the conviction that it owes its present appearance to the action of the great basaltic eruption, which has enveloped it and the organic remains. The greater number of the shells are converted into chert, but a few retain their original structure; and in some instances the calcareous matter has been converted into crystals of calcareous spar. Many internal casts of entire shells are found in the substance of the rock, to which they are united at a few points only, a greater or less space being left unoccupied; in others, the entire shell is converted into siliceous matter, retaining the appearance even of the ligaments unaltered; and fortunately, in a few cases, the hinge and teeth are excellently preserved.

Numerous fragments of shelly rock, differing much in appearance, lay scattered about over the table-land; consisting partly of a fine blood-red chert, like that above described, and containing the same shells. The gray chert was more sparingly distributed, and the Unios did not occur in the other fragments. Some of them, composed of a tough white clayey stone, so soft as to soil the fingers, contained Physæ,

Paludinæ, and Limneæ, mostly converted into calcedony, but others also retained their original structure, and effervesced with acids. Portions of charred vegetable matter, resembling small fragments of grasses and reeds, occurred in these and the harder cherts. Other specimens are composed of a greenish blue crystalline mass, resembling an ore of copper (but it is of low specific gravity, and contains no trace of that metal), and the shells contained in them are converted into the most beautiful crystalline quartz, retaining the form of every convolution of the Physæ and Paludinæ. The cells of this stone are often coated with fine silky crystals. Masses of a hard coarse chert consist almost entirely of Gyrogonites, but contain many of the same Physæ and Paludinæ. This rock appears to have formed beds of about half a foot in thickness; but it was not discovered *in situ*. A stratified rock was, however, found in the neighbourhood, resembling some specimens of the argillaceous limestone of the diamond districts, but consisting of a compact whitish chert, which contained Paludinæ, and the finest specimens of Gyrogonites. (Plate I. fig. 1.) Night prevented the connexions of this rock from being determined: the strata were, however, ascertained to be of considerable extent, and to be much buried in the soil; there were also numerous fragments of siliceous rock, partly converted into a black bituminous flint, or a coarse quartzose rock, partially altered into calcedony, by which most of the shells were also replaced.

The masses of red chert protruding from the basalt contained, besides the Testacea, small portions of silicified wood, and what I consider to be the fragment of a bone and of the tooth of a mammiferous animal. The specimens, however, are too imperfect to admit of any certainty as to what they really are; but it is not unlikely that such remains should occur, and I therefore do not suppress what may lead to a more successful inquiry.

On descending towards Hutnoor, granite, presenting a concentric, ligniform surface, from the unequal decomposition of the quartz and felspar, occurs at a short distance from the fossils.* With this exception, the basalt continues of the same character as before, and fragments of red or deep black chert, containing Paludinæ, are found in the beds of torrents; and at Hutnoor they occur in the trap. There is much calcareous matter mixed with the soil, or collected in nodules, and it appears to be derived from the lime contained in the basalt, or between its laminæ. On the pioneers attached to our camp penetrating, at Elchoda, through some strata of tabular basalt to obtain water for the troops, seams of a pure white pulverulent lime were found between

* A similar appearance has been observed at the foot of the Nirmul pass, at the iron mines of Deemdoortee, and in Bundlecund.

the layers.* At Hutnoor fragments of a compact blue limestone, not to be distinguished from that of the diamond districts, were collected; and the rock to which they belonged was found in the descent from the first of the three principal terraces by which the road leads to the northern base of the hills. The strata were much inclined and broken, but the forest was so thick that I could not trace them for any distance. After descending to the second terrace, the surface rock suddenly changes to a white, horizontally-stratified limestone, almost entirely composed of large bivalve shells, the edges of which decomposing more slowly than the cement, the natives have applied to it a name signifying impressions made in clay by the feet of sheep. The thickness of the bed in one place, where it is intersected by a torrent, is 12 feet, and it rests directly on red granite. A great spur, from the upper part of the mountain, extends across the terrace, rising precipitously above the fossiliferous limestone, a few hundred yards from the spot where it rests on granite, and has buried the continuation of the stratum under an accumulation of basaltic *débris*. Where the limestone becomes concealed in the basalt, a friable, grey, cellular mass, resembling ashes, occurs, apparently imbedded in both these rocks. The fossils are composed of granular limestone, the matrix consisting of calcareous matter mixed with the ash-like substance, and small fragments of granite. Some of the shells are of great size, but they are ill preserved, and I found only one specimen with the valves united. These shells I erroneously considered to be marine (principally from the appearance of those represented in Plate II. figs. 4 to 8, and some of the large flattened specimens). Mr. Lonsdale, however, who had the kindness to examine some of them, considered their general character to be that of fresh-water species. I had previously detected, in a fragment of a compact argillo-calcareous stone found at the bottom of the little cliff where the granite is seen to underlie the fossils, a number of very perfect Melaniæ; I, therefore, re-examined the different specimens, and detected in them fragments of the same kind as those in the limestone; and Mr. Sowerby has since been able to extract from the latter, specimens sufficiently distinct to be identified with the *Unio Deccanensis* (Pl. II. figs. 4 to 10,) found in the chert at Munnoor, and another species (*Unio ? tumida*, figs. 11 and 12) not yet discovered elsewhere. No other fossils were found in this locality.

When it is considered that the accumulation of fresh-water shells occurs on the precipitous descent of a mountain range, ascended with much difficulty by travellers, it will be evident that the aspect of the country has been entirely altered since these animals lived.

* The same was observed in Bundlecund by Captain Franklin. (Asiatic Researches, vol. xviii.)

Country between the Sichel Hills and Nagpoor.

Towards the foot of the pass, the rock changes from the nodular basalt to amygdaloid; and near its junction with the granite, masses of greenstone porphyry, with large crystals of felspar, occur. The granite then reappears, protruding in rounded masses through the soil of the level country around Yedlabad. The bed of a stream near that town is strewed with fragments of blue limestone and schist, resembling those of the basins of the Pennar and Kistnah; and higher up the stream a fine white quartzose sandstone, having a few imbedded fragments of quartz, is found *in situ*. It dips at a slight angle to the south-west.* The surrounding country is covered by a deep basaltic soil, so that the rock on which it rests could not be discovered; but the argillaceous limestone, passing, in its upper strata, into a greenish or red schist, is traversed by a stream a few miles to the north. Short ranges of trap hills, some of them at nearly right angles to the Sichel mountains, occur to the north-east; and beyond them, an extensive tract of sandstone has been traced for a great distance along the Wurdah.

At Zynad, argillaceous limestone appears on the surface for several miles, and agrees in every particular with the compact marbles of the diamond districts of the Pennar and Kistnah. The strata sometimes dip at an angle of 40 degrees, but they are in general nearly horizontal, the edges of the layers being disposed in steps on the slopes of gently-rising grounds. Rock crystal and calcareous spar are distributed in thin seams between the strata, as well as through the substance of the rock; and along the vertical partings of the strata there are rows of circular cavities, which are generally empty, but are sometimes filled with calcareous concretions. In a few instances these hollows occur out of the line of fissure, and entirely penetrate the stratum, being connected below with horizontal channels of the same kind. On the surface, calc-tuff (Kunkur) is very abundant, often adhering to the strata, or investing fragments of the rock.

The same appearances are seen near the diamond mines of Chinoor on the Pennar, where the strata are much disturbed, and basaltic pebbles cover the banks. The only explanation which can be offered of the phenomena in both those distant localities is, that the extrication of gaseous fluids and water from below had taken place in the lines of fissure, and had dissolved a portion of the limestone, which was again deposited in the great accumulation of tuff and conglomerate so remarkable in these places. That they at all indicate the "argillaceous

* Minute undulations, resembling those formed by the ripple of running water, were observed on this sandstone, in a seam not quite parallel to the line of stratification.

limestone" to be of fresh-water origin could never be imagined by any who had seen the rock in question, which, wherever it occurs in the south of India, is entirely devoid of fossils.* This supposition is confirmed by the phenomena exhibited at the hot springs of Urjunah, which rise in the same rock, and where bubbles of carbonic acid are extricated through round holes in the mud covering the bottom of the rivulet, the water of which, being loaded with lime, a calcareous tuff is rapidly deposited.

A gentle elevation, extending three miles to the east of the village of Zynad, is composed of this limestone, and it rises very gradually towards a small conical summit, composed of coarse vesicular basalt, which has broken through and covered the limestone. A portion of this rock appears to have been displaced in a singular manner. A wall of perfectly vertical stratification, about three feet thick, projects nearly as much from the general surface, and consists internally of the same limestone as that which it appears to cut at right angles, while externally it is singularly irregular and altered, being converted into a beautifully crystalline limestone, with quartz minerals.

To the north of this place, as far as the Payne-Gunga river, the country is flat, covered with basaltic soil or rock connected with insulated trap hills, and intermixed with jaspers, resembling those so common near Bangnapilly, and perhaps derived from the argillo-calcareous schists occasionally seen in the water-courses. The pebbles of the Payne-Gunga consist mostly of calcedonies of a reddish colour, and of argillaceous limestone, and they are in many places consolidated into a conglomerate by the calcareous matter with which all the waters of the district abound. In a layer of this conglomerate, projecting from the alluvial soil of which the bank is composed, numerous recent shells are imbedded. The limestone and its incumbent schists are seen north of the river, and they abound in springs and streams loaded with lime, which is deposited as calcareous tuff in the water-courses. Masses of the same substance, several feet in height, project from fissures in the rock, or compose conical eminences of white "Kunkur," which are scattered over the black basaltic plains.

Proceeding a little further towards the Pindee hills, in which the principal of these streams takes its rise, sandstone appears on the south bank of a ravine; and on the opposite side, at a lower level, the "argillaceous limestone" so often mentioned, has been raised by some violent

* This assertion may, in the progress of knowledge, be found to be erroneous; but, having carefully looked for fossils during extensive journeys through districts principally composed of this rock, I doubt whether such will be the case. Fossil plants have been reported to be found near Gundycottah; but these I ascertained to be mere dentritic markings on the surface of the strata.

forces into irregular gothic arches, overlaid by partially broken but horizontal strata. The spaces within the arches are filled with fragments of the same rock forced from below. Hot springs, having a temperature of 87°, rise through the limestone, and globules of gas escape from round holes in the *débris* and mud covering the bottom of the ravine. On endeavouring to collect a quantity of the gas, there were found to be considerable and irregular intervals between each jet of air. A recent calcareous sandstone is formed in the bed of the stream, by the *débris* derived from the quartzose sandstone of the southern bank being agglutinated by the carbonate of lime of the springs.

A range of low hills, having rounded summits, with conical elevations projecting from their sides, runs in a north-west direction, three-quarters of a mile from the hot springs. The cap of these hills, where the Pindee Ghàt passes over them, consists of the argillaceous limestone, and the large slabs of which it is composed are fissured in various directions, slightly convex upwards ; and, when taken in the mass, they have an anticlinal dip. On the summit, the strata are horizontal and in several places are remarkably altered, the argillaceous and siliceous ingredients having arranged themselves into a black chert, and a mixture of calcareous matter with streaks of a white or pale blue enamel resembling calcedony. The central parts of these bands are composed of minute quartz crystals ; and irregular drusy cavities, coated with amethystine quartz, occur in the blackened flinty portions. There cannot be a clearer indication of the action of heat on a rock of a mixed character than this, even when seen in hand specimens. The whole of the base of the hill is composed of the usual black concentric basalt, the nuclei of which are exceedingly hard and contain much olivine ; and to its intrusion the alteration of the limestone, with its separation from the strata below, is, without doubt, to be ascribed.

Many hills composed of concentric basalt are scattered over the neighbouring country, in insulated masses or long ranges rising in terraces, and having flattened summits. The sides of the hills between the terraces are steep, and their outline is well defined ; the rock also is black and devoid of vegetation. The terraces occur at very different levels in different hills, rising from the same plain ; and their whole appearance indicates that their remarkable form is due to the circumstances which attended their elevation ; and that they have not been subjected to any extensive denudation.

About five miles north of the hot springs of Urjunah and four miles south of those of Kair, sandstone caps a gently rising ground, covered with basaltic soil. Near the last-mentioned town many hot springs rise in the argillaceous limestone, which has been remarkably broken up and altered by the globular basalt protruding through it in different

places, in masses several of which are only a few yards in circumference. The limestone is, for the most part, nearly horizontal, but it is occasionally more or less inclined, and, as is usual with this formation, it has no regular direction or line of bearing. In a deep well near the village, the water of which is of the usual temperature, the limestone is unaltered; but above the principal hot spring some of the most remarkable effects of igneous action in changing a stratified rock are exhibited. The principal part of the small hill is a whitish limestone, the stratification of which is obliterated, and the rock projects in irregular masses full of cavities passing deep into the mass of limestone, which is partly crystalline, and in many places mixed or coated with jasper and quartz crystals. Much calcareous tuff (Kunkur) is associated with these altered rocks, and it fills up many of the cavities; it is also found in the divisions of the nodular basalt, and masses of it, scattered over the surrounding country, are the only remains of springs which have been long closed up. Some portions of the rock had the appearance, on the surface, of a semifused brick, and had assumed something of a regular arrangement, while the centre was composed of the limestone little altered. Large masses of porous scoria also lay about.

The principal springs issue at the foot of the rising ground, where the rock is most remarkably altered. Their temperature (87°) was the same as that of Urjunah, on the other side of the Pindee hills, and it did not vary during the hot and cold months of 1831 and 1833. The water of this and many other springs is said to be equally copious at all seasons, covering the neighbouring country with the richest vegetation, when all beyond is a black and parched waste. On issuing from the rock, the water is sensibly acid, and in one spring, carbonic gas escapes with the water. It is remarkably agreeable to the taste, and sparkles in the glass, as well as where the stream passes over rapids. It contains a little muriate of soda, a minute quantity of sulphates, and much carbonate of lime in solution, which is deposited on boiling, and in the bed of the rivulet, where it has formed considerable masses of rock, chiefly composed of the petrified vegetation of the banks. So quickly is this deposit formed near some little falls, that shells appear to be imprisoned and entombed while adhering to the face of the rock; and tufts of grass are encrusted with sediment while their roots are still alive. If any doubt remained as to the nature of the nodular limestone, known in India by the name of "Kunkur," it would be removed by the sight here exhibited of all gradations of this substance actually forming, and varying from pulverulent lime to a crystalline rock. The water is probably derived from a great depth, the springs having, as already stated, the same temperature as those of Urjunah, and not being materially diminished by the failure of the annual rains.

Sandstone forms the surface rock in different directions over the surrounding country, but I had an opportunity of examining it carefully only at Won, eight miles north of Kair, its junction with the limestone being concealed by basaltic soil, mixed with calcedonies, fragments of that rock, schist, and of a coarse puddingstone, which I did not find *in situ*. The hill of Won is composed of sandstone, dipping in all directions from the apex, and varying in colour from white to red and yellow. It contains also ferruginous grains or scales, either in seams or disseminated through its substance. In a fragment of this kind much resembling the cement of the Bangnapilly diamond breccia, a fossil was discovered having a compact structure and deep black colour, and it is probably a portion of a hollow, compressed vegetable, the centre of which is filled with the sandstone. It is the only instance that has come to my knowledge of a fossil being found in the sandstone of Southern India; and as the rock corresponds in geological position and mineralogical characters with the diamond sandstone, the fact is of considerable interest, even if the formations were not found to be continuous, as will be stated hereafter. The specimen is deposited in the Museum of the Asiatic Society of Bengal.

Sandstone, argillaceous limestone, and schist constitute the building stones of the surrounding country, which is much buried under basalt and a black alluvial soil containing calcedonies, jaspers, &c. A few miles south of Chicknee* (where the fossils were again met with), the red schist found above the limestone south of the Urjunah hot-springs and in various places of the diamond districts of the south, reappears, intermixed with protruding masses of basalt, which have altered it in the most singular manner,—the lime of which it is in part composed being converted into a fine crystalline mineral, in which the red clay is enveloped or diffused, giving the rock and even hand specimens a very striking appearance. Near Chicknee, the schist rises slightly towards a basaltic ridge, in which the fossiliferous chert is likewise imbedded. The schist is divided into minute rhombs by vertical partings, in which veins of calcareous spar from an eighth to half an inch thick have been formed, and give it a beautiful, reticulated appearance. Lime is found in the schist, and portions of the red clay are enveloped in the crystalline limestone, which contains no magnesia.

The fossils occur on the surface, or are imbedded in nodular basalt over several miles, being found in blocks of indurated clay, chert, and flinty slate. The appearance of the indurated clay is the same as in some of the specimens from the Sichel Hills, but the clay is harder, full of cavities, and in some cases passes into perfect chert, or has waved lines of quartz or opalized matter diffused through the substance of the

* Fossils were first found at Chicknee by Mr. W. Geddes, May, 1829.

mass. Many Physæ, Paludinæ, and a few Limneæ of the same species as those already noticed, are found in this indurated clay or imperfect chert. Some of them are entirely converted into calcedony; others have the lime replaced by quartz, which is finely crystallized and covers the surface of the convolutions; or the columella only is preserved, passing across an empty cast of the shell. In some cases, however, the structure of the fossil is unaltered, and it effervesces in acids. Flinty slate without organic remains occurs in the neighbourhood of those amorphous masses, and many fragments of the same kind, containing large compressed bivalves, are scattered about. In one block of this kind portions of palm wood, mineralized by black flint, intersected by fine veins of a light blue opal (of the same kind as occurs in some of the specimens of fossil wood from Antigua, lately presented to the Society by Mr. Stokes), was found associated with compressed very thick bivalve shells, probably referable to the same species as those of Munnoor.

Every appearance presented by these rocks indicates the action of the semifluid basalt on the beds of mud and sand, probably derived from the neighbouring sandstones and schists, in which the shells previously existed.

At Hingan-ghàt,* a few miles further to the north, considerable fragments of silicified palms and other plants were found in a black chert lying on the basalt, and similar masses, but without fossils, were imbedded in it. I met with no organic remains to the north of this town, the whole country as far as the city of Nagpoor being covered with a rich black soil, from which insulated basaltic hills with flattened summits rise abruptly.

Of these hills the most remarkable is that of Seetabuldee, which is based on decomposing gneiss and mica slate. To Dr. Voysey's description† I have nothing to add; but, as it has been inferred‡ that the "flattened summits and long flat outline" of the low ranges connected with this celebrated hill, and forming the eastern part of the great trap

* In examining with the microscope sections of some of the silicified wood from the district described, a specimen from the chert of Hingan-ghàt appeared to me to be bone, and Mr. Owen, who has had the kindness to examine it, has ascertained it to belong to a mammiferous animal. He has favoured me with the following note on this important fossil:—

"A section of this fossil was prepared sufficiently thin to allow of its being examined by transmitted light under a high magnifying power, when it was found to possess the structure characteristic of bone. Sections of 'Haversian canals,' with their concentric lines, were everywhere present, interspersed with numerous Purkingian cells or corpuscles: the size and disposition of these characteristic parts of the osseous structure agreed with those of the bones of the Mammalia. It was highly satisfactory to find the microscopic test as available in demonstrating the presence of bone, when ordinary characters and the unassisted eye would have left the matter doubtful, as it is in reference to the determination of the teeth."—July 1839.

† Asiatic Researches, vol. xviii. ‡ Geological Transactions, Second Series, vol. iv. p. 410.

district, are composed of basalt having the same stratified appearance as that of other parts of the formation, it is necessary to mention that they are formed of globular basalt such as has been already described, or of basaltic columns of very regular forms, which diverge from the centre of the hill and incline outwards at an angle of 45° with the horizon, or form a figured pavement on the flat summits.

Origin of Minerals in Trap Rocks.

The lower part of the hill of Seetabuldee itself exhibits a tendency to columnar structure, caused by horizontal and vertical partings, the sides of which are coated with thin plates of calcedony, and, according to Captain Jenkins,* of calc spar. These minerals are not confounded with the substance of the basalt, and may be the result of infiltration or sublimation of siliceous and calcareous matters. In no other situation did I meet with an example in which either of these processes would account for the occurrence of the calcedonies, zeolites, calc spar, &c. found in the amygdaloids and nodular basalt of India. Almost everywhere calcareous spar is more rare than siliceous minerals, which would not be the case were they derived from infiltration, if we are to interpret the past by the present operations of nature. Wherever I have met with the basalt, and in the neighbourhood of every greenstone dike or insulated mass of that rock, and under every layer of basaltic soil in India, calcareous matter is deposited, and has even occasionally a crystalline structure. In the escarpments of the Mysore ghàts, veins of basalt, not two inches thick, ramify through the granite, and are coated with a compact layer of carbonate of lime. Voysey found the granite in the neighbourhood of the basalt intermixed with calcareous matter, indications of which I have myself seen in the deposit of tuff on the summit of granitic logging-stones near greenstone. If, then, we suppose infiltration to have deposited the calcedonies, agates, &c. &c. when chemical action is presumed to have been more powerful than at present, a greater number of the cavities would have been filled with lime than with such intractable substances, which is not the case. These are also frequently intermixed with the basalt in a manner which could have been produced only by their being formed simultaneously. I have seen masses of calcedony, passing into a black mineral not to be distinguished from the surrounding basalt. They also occur in the compact nodules where no fluids could have had access, and even in the cavities of the Seetabuldee basalt, lined by an impervious glassy coat. In this rock, likewise, calc spar occurs, penetrated by needle-like crystals of the same substance, invested with a crust of the basalt and

* Asiatic Researches, vol. xviii. p. 199.

connected with each side of the cavity, and resembling chiastolite in structure. It is indeed impossible to conceive how many of the appearances presented by the agates, cornelians, or drusy cavities in calcedony, partially or entirely filled by quartz crystals, or a central mass of calc spar, could be formed in the way supposed, as the first coating of silex would effectually close out the further access of the aqueous solution of that substance; nor could layers so formed separate into distinct cavities, having both sides covered with quartz crystals, as they are sometimes seen to do. It is, however, only by a careful study of the rocks themselves that this can be fully understood. I have selected a few specimens to show that the majority, if not all the minerals of the Indian trap rocks, are not formed by infiltration. One of these, perhaps, deserves particular notice; it is a mass of calcedony, 8 or 10 inches in length and 6 or 8 in diameter, of a conical shape, and was found imbedded with its apex downwards between the globular basalt, and impressed with the irregularities of its surface. In another of these specimens the upper part is perfectly flat and smooth, without any impressions of the basalt, and is composed of a thick covering of cacholong, parallel stripes of which appear to indicate the slow cooling of the surface. The centre of the mass is composed of quartz crystals, radiating to the centre, which is occupied by calcareous spar impressing or impressed by the quartz. The mode of its occurrence increases the conviction in my mind that the only correct theory of the formation of such minerals in trap rocks is the play of the molecular attractions existing between similar particles of matter. That so eminent an inquirer as Dr. Turner should have asserted that all calcedonies, rock crystals, &c. even when occurring in volcanic rocks, are the result of aqueous infiltration,* I can only account for by the difficulty of explaining how carbonic acid is retained at high temperatures in any other way than by supposing a great pressure to have existed at the time the rock was in an ignited state; but of the existence of which proof is often entirely wanting where crystals of carbonate of lime occur. The phenomena exhibited by the vesicular trap, scoriæ, and porous chert associated with the Indian basaltic and fossiliferous rocks, satisfied me that at the time of their formation they were subject to no pressure sufficient to retain the carbonic acid of the altered limestones, and of the shells and calc spar inclosed in the geodes; but no other explanation presented itself, till I was informed by Mr. Faraday of his beautiful experiment of exposing carbonate of lime in perfectly dry air to the heat of the oxyhydrogen blowpipe, without driving off its carbonic acid. In the simple apparatus employed by him to show that the reten-

* Lecture on the Chemistry of Geology, by Dr. E. Turner, Edin. New Phil. Journal, Oct. 1833.

tion of the acid depended on the absence of moisture, no pressure of any consequence could be exerted on the lime. Guy Lussac has lately published some experiments on the effect of aqueous vapour in assisting the escape of carbonic acid from limestone, and concludes that its agency is trifling;* but as he does not appear to have taken the precaution of drying the atmospheric air by passing it through sulphuric acid, as was done by Mr. Faraday, they cannot be considered as invalidating the beautiful results obtained by the latter. His observation, however, that the water contained in limestones is driven off before the carbonic acid and at a much lower heat, is important, in showing that the calcareous matter in a rock exposed to volcanic action may lose its water before the carbonic acid, and be thus reduced to the state of the carbonate of lime in Mr. Faraday's platinum tube. These facts will assist in explaining the anomalies observed in the fossils of the district above referred to, which often retain their carbonic acid when portions of the rock in which they occur have been fused by the inclosing basalt, while other portions are vesicular from the escape of gaseous matters. The whole phenomena, indeed, would admit of explanation by supposing, what must in fact have occurred, the presence or absence of moisture during the various degrees of heat to which the rocks were exposed in the progress of the eruption, and in the course of cooling. A shell, in one part of a rock, may thus retain its carbonic acid, while in another portion it may be reduced to quick-lime, subsequently carried off by the water, leaving only a cast; and a third may be replaced by silica, or the form of its convolutions taken by fine quartz crystals, perhaps derived from silica rendered gelatinous by the lime with which it was ignited.†

In stating these views, I venture only to express an opinion forced on me by the phenomena under description, and which appear to explain some of them better than the theory of pressure, which, however useful in removing the prejudices against the igneous origin of the trap rocks, has been injurious in leading geologists to admit too easily the existence of aqueous pressure, or extensive denudations of solid rocks, supposed to have confined the carbonic acid at the time of eruption. No doubt pressure is an efficient agent in some cases,‡ but not in many to which it has been applied.

The trap terminates in the line of section, a few miles to the north of the city of Nagpoor, and is succeeded by a red sandstone, the strata

* Annales de Chimie et de Physique, Oct. 1836.

† For a knowledge of the fact, that lime calcined with finely-divided silica acts like the fixed alkalis in rendering it gelatinous and soluble in weak acids, I am indebted to Captain Smith, of the Madras Engineers, F.R.S.

‡ Transactions of the Royal Society of Edinburgh, vol. vi. p. 120.

of which are bent, fractured, and converted into a compact quartz rock, at the point of contact with the granite which has burst through it. Within a few hundred yards of the ravine where these phenomena were observed, mica slate occurs, and a little beyond, some hills of gneiss. A bed of granular limestone is quarried at the foot of a conical hill of basalt, in part composed of a scabrous quartzose and calcareous rock, abounding in drusy cavities, calcedonies, and cornelians. Further north, granite veins pass through a much-elevated limestone, varying in colour from red to grey and back, and the stratification of which is nearly obliterated. The gneiss and mica slate forming the neighbouring hills are also penetrated by dikes and masses of granite.* To the north of this district are 50 miles of a wild mountain country, composed of granitic rocks, with trap in the ascents and tops of the passes; the basalt then reappears, and composes great part of the valley of the Nerbudda.

In a direction south-west of Nagpoor the nodular basalt is the only formation met with as far as Baitool (90 miles), where granitic rocks reappear, but are succeeded by fine-grained sandstones with traces of coal and penetrated by trap dikes ranging from S.E. to N.W.† Here the sandstone rises into mountains, and constitutes what appears to be the continuation of the range forming the division between the valleys of the Taptee and Nerbudda rivers; and "indurated clay," containing casts of the same shells as those of the Sichel range, also occurs.

Before proceeding to notice more particularly the fossils and the evidence they afford of the geological era of the intrusion of the basalt, it is necessary to make some observations on the Sichel range, and the connexions of the several formations occuring in the district described. The basaltic rocks of Nagpoor and of the country to the south have been considered by every observer to form the eastern part of the great basaltic formation of Western India, with which it is continuous, and with which it agrees in every particular of general character and mineralogical structure, and in being connected with stratified rocks, which, as far as is yet known, are of the same age. The only difference is, that towards the eastern limits of the formation, the hills are less elevated and the trap breaks through the granite and stratified rocks, while to the west the mountains are, with a few exceptions, entirely composed of basalt from the level of the sea to the loftiest summits.

Lonar Lake, &c.—The Sichel hills, which have heretofore attracted little attention in a geological point of view, terminate to the west in the neighbourhood of Lonar, near what appears to have been a vast crater

* Captain Jenkins, in Asiatic Researches, vol. xviii.

† Lieutenants Miles and Finnes, Journal of the Asiatic Society of Bengal, February 1834, and Dr. Spilsbury, August 1834.

in the centre of the great basaltic district. As it is the only instance of a volcanic outburst discovered in this immense Plutonic region, a more detailed account of it than has yet been given to the public may not be unacceptable.*

It is a nearly circular or oval depression, in a country composed of tabular and nodular basalt, and sloping gently towards it on every side. (Plate I. fig. 2.) It is between three and four miles in circumference at the upper margin of the precipitous escarpment which rises from the bottom of the valley about 500 feet. The extent from which the water is collected may be about six miles in circumference, but no measurements were made. Two small streams fall into it from above; one issuing from a pagoda, to which it is carried from the gentle slope behind; and the other passes over a small cliff, on which it deposits a considerable quantity of stalactite. The sides of the crater are covered with a forest inhabited by tigers and game; and the bottom is occupied by underwood, a few fields, in the irrigation of which the water of the streams is nearly expended, and by a small lake of salt and bitter, greenish water, surrounded by a muddy shore, and varying in size at different seasons. Many sweet springs issue from the saline mud, and a well is built within its highest level, the water of which stands at the same height as that of the lake, though issuing from a depth of nearly twenty-four feet.

I have carefully examined the water of this well, and that of the small stream at the pagoda above. This last had a specific gravity of 1000·6; and 2,000 grains, evaporated at 212°, gave a solid residue of $\frac{7}{10}$ of a grain, the greater part of which consisted of muriate of soda with a little sulphate, and the remainder of carbonate of lime. The water of the well below had nearly the same specific gravity, but contained, in 2,000 grains, one grain of solid matter, of which $\frac{7}{10}$ of a grain were soluble in water, and contained muriate of soda and a little sulphuric acid and lime; the insoluble part consisted of carbonate of lime. Neither of the waters contained any trace of alkaline carbonates or of magnesia. It is unnecessary to go further into the analysis here, as another bottle of the same water had a higher specific gravity and contained more lime, a circumstance sufficiently accounted for by the escape of a portion of the carbonic acid from the other specimen. The water of the lake is clear, and has no unpleasant smell; but the mud at its bottom is strongly impreg-

* Captain Alexander has published a notice of this lake in the Transactions of the Literary Society of Madras, and in the Edinburgh Philosophical Journal; but he must have examined it very cursorily or he would not have overlooked its real nature, and stated it to be unfathomable, when, in fact, the water is everywhere shallow. An extract from a private letter to Mr. Prinsep, and published in his Journal for June 1831, was written before I had myself examined the chemical history of the lake.

nated with sulphuretted hydrogen. In February 1834, when the specimens were collected, the lake was in no place more than five feet in depth of water and mud, but when full it may be eight or ten feet deep in some parts. A layer of salt two or three inches thick covered the bottom *under the mud*, and when broken up and removed, was found to be composed of a middle plate, with radiating laminæ above, and having a striated appearance below. That obtained by diving and bringing up baskets of the black mud, at a season when there was much more water in the lake,* was also formed under the surface of the mud in lamellar spicula radiating in every direction.† The salt accumulates slowly, and is collected only once in several years, the quantity having diminished in consequence of the mounds erected above the edge of the crater, to regulate the supply of water, having been neglected; but it is evident, from the great beauty of the specimens obtained, that the quality is not affected by this cause. The salt is collected at the end of the dry season, when the water is low; and I observed mounds of the black mud on the banks, covered with an efflorescence of tubular crystals. The salt is used for washing and dyeing chintzes, &c., and is exported to considerable distances. I imagined that the water of the lake in which such large quantities of salt were deposited was saturated; but I found its specific gravity to be only 1027·65, a solution of the salt itself obtained from the bottom at the same time being 1148·4; and the water rapidly dissolved the crystals thrown into it. On analysis, the salt was found to consist, in 100 parts, of carbonic acid, 38; soda, 40·9; water, 20·6; insoluble matter, ·5; and a trace of a sulphate. This nearly corresponds to the composition of the trona or striated soda from the lakes of Fezzan, examined by Mr. R. Phillips;‡ but approaches somewhat nearer to the equivalent numbers of the sesquicarbonate established by that analysis, which is to be ascribed to the greater purity of the Lonar salt. The water of the lake contained, besides, a little potash, muriate of soda 29 grains, sesquicarbonate of soda 4·2 nearly, and sulphate of soda ·1 of a grain in 1000 grains of the water. No lime could be detected in it, nor did I discover any magnesia. These facts confirm Berthollet's theory of the formation of carbonate of soda in the natron lakes of Egypt, viz. that of a mutual decomposition of the muriate of soda and carbonate of lime when in a pasty state.

The striated soda of Fezzan and of this lake, containing half an

* July 1824.

† The natron of a lake near Maracaybo in South America occurs in the same way, the Indians breaking up the layers of salt with long poles; and then, by diving, they remove it from under a bed of mud which covers it, and they place it in small canoes, as is done at Lonar. —Journal of the Royal Institution, vol. i. p. 188.

‡ Journal of the Royal Institution, vol. vii. p. 294.

equivalent more of carbonic acid than can be furnished by carbonate of lime, renders some modification of his theory necessary; and the most probable explanation appears to be that the carbonic acid by which the lime is held in solution in the mud furnishes the acid, and perhaps indicates the existence of an unstable sesquicarbonate of that substance; which is not improbable from other facts in the history of the union with that acid. This was suggested by my friend Captain Smith of the Madras Engineers, and explains the circumstance sufficiently.

Like most points in physical science, these observations have other and more extensive applications than that of affording an explanation of the production of natron in this lake. Carbonate of soda is extensively distributed over the surface of the soil in various countries, more especially in the basaltic portion of Central and Western India, and in the limestone districts of the south; the real relations of which have been a subject of discussion amongst Indian geologists, and inferences unsupported by fact have been drawn from it. In all the places where I have met with it, or of which detailed information has been obtained, muriate of soda and carbonate of lime existed in the soil, and the natron was found on the surface of the moist earth or mud. Near Gundycottah on the banks of the Pennar, common salt is interstratified with the upper schistose strata of the argillaceous limestone on which the sandstone rests; and on the surface of the neighbouring soil, natron, contaminated with much muriate of soda, is collected and used in washing and in glass-making. The salt associated with the limestone, and the water of a saline well dug through it, having the specific gravity of 1002·5, contain common salt and a little sulphate without any carbonate of soda, which is no doubt produced in the same manner as the Lonar salt. I did not ascertain whether it was also a sesquicarbonate, but I have examined a portion of native carbonate of soda from another part of India, with which Mr. Faraday had the kindness to furnish me, and I found it to be composed of a mixture of that salt with muriate of soda and a little sulphate. The same is probably true of the carbonates found in other countries in similar situations.* A specimen, however, procured from the water of a deep well near London, passing through the London clay into the chalk, which I received from Professor Daniell, contained the carbonate; but as the sesquicarbonate is decomposed by a low heat, no inference can be founded on the examination of specimens obtained, as this was, from the boiler of an engine.

The absence of lime in the water of the Lonar Lake is a remarkable

* The carbonate of soda formed by the incineration of saline plants in the deserts of Northern India, and by the deflagration of nitrate of soda and charcoal in the south of the Peninsula, must not be confounded with the natron found in the soil.

circumstance, but easily accounted for, as the sesquicarbonate of soda and the water itself precipitate the sulphate and muriate of lime, notwithstanding the mutual decomposition they undergo when in a semifluid state. The Lake of Ourmia, in Persia, is stated by Dr. Marcet to contain no lime, although of a specific gravity of 1165·07, and abounding in sulphates and muriates. This appeared very remarkable in an inland sea nearly 300 miles in circumference, situated in a volcanic country. On referring to the works of travellers,* it appeared that the streams flowing into it abounded in lime, which is deposited in large quantity in the form of a beautiful travertine. The lake is shallow, and at certain seasons much of it is nearly dry ; the water is clear and transparent, but the mud of the bottom is loaded with sulphuretted hydrogen, and thick layers of salt, formed in it under the water, are re-dissolved on any agitation. No fish can live in it. All these phenomena are exact counterparts of those exhibited at Lonar, but no information is given as to the salt collected from its saline mud, except that Sir John Malcolm states the salts are bitter and different from those of the sea. I am, therefore, strongly impressed with the conviction that sesquicarbonate of soda is formed from its waters as at Lonar, and precipitates the lime. Dr. Marcet, however, has given, in the Philosophical Transactions for 1819, the results of an examination of a small quantity of this water, which he states to be as follows :—

1. Precipitate from 500 grains of the water by nitrate of silver.. 237·0
2. By nitrate of baryta .... 66·0
3. Magnesian precipitate by carbonate of ammonia and phosphate of soda .... 10·5

And he infers that, although it contains no lime, it yields twenty times as much sulphuric acid and six times as much muriatic acid as sea-water does. But Dr. Marcet had only 150 grains of this water to operate on, and merely gives in a tabular form, along with many specimens of sea-water, the quantity of precipitate caused by the various reagents ; and there is no evidence that the precipitate from muriate of baryta was not, in part, caused by carbonate of soda. It is, at all events, worthy of the inquiry of future travellers.†

The Lake of Ourmia, like that of Lonar, contains potash, which I did not detect in the springs running into the latter, but its source is no doubt in the decaying (and when I visited it, burning) trees on

* Sir John Malcolm's History of Persia ; Sir Ker Porter's Travels ; Ouseley's Travels ; Journal of the Geographical Society, vol. iii. &c.

† If a carbonate exists in the water, it must be of the same composition as that of Fezzan, Maracaybo, and Lonar, as the carbonate would precipitate the magnesian salt, which the sesquicarbonate would not.

the surrounding precipices. The sulphuretted hydrogen adhering to the clay has been supposed to be derived from volcanic sources, but I have observed the same phenomenon in the salt-water inlets along the Indian coast, wherever the bottom contained argillaceous and carbonaceous matter; and it even goes so far as to form considerable quantities of sulphur, and, I have reason to believe, sulphuric acid, although on this point the proof is defective. The effect is to be ascribed to the decomposition of the sulphates of the water by the carbon; and the clay probably only prevents its passing off into the air, or mixing with the water, by the power of adhesion. Similar actions have gone on in former times in the alluvium on which the city of Madras stands, and probably in more ancient deposits.*

The ancient crater of Lonar seems never to have been an active eruptive vent, as no scoriæ or lava currents can be traced around its margin, which is too distinct and unaltered to admit of any probability of these having been subsequently removed by denudation. A certain degree of forcible elevation was sustained by the margin of the lake, when the explosion or subsidence happened from which the great depression took its origin.

From Lonar the basaltic district extends to the south as far as Beder; to the west, 200 miles to Bombay; and northward, to the banks of the Nerbudda, near the ancient cities of Indoor and Mhysir, reported to have been buried at a remote period under volcanic eruptions. To the east, the great basaltic country of Berar extends as far as Nagpoor; and the Sichel range passes in a S.E. by E. direction to the confluence of the Wurdah and Godavery, and towards the eastern ghàts. Hot springs and streams, loaded with carbonate of lime, occur along the line of elevation of these mountains at Mahoor, Urjunah, Kair, Byorah, and at Badrachellum, a short distance above the pass through which the Godavery reaches the alluvial plains of the coast. The spring of Byorah is surrounded by sandstone and limestone rocks, and carbonic acid escapes with the water, which has a temperature of 110° and holds lime in solution.† That of Badrachellum, which rises in the sandy bed of the Godavery, has a temperature of 140°, and contains sulphuretted hydrogen, also sulphates and muriates of soda and lime. A sandstone, resembling the cement of the Bangnapilly diamond breccia and the rock of Won, protrudes from the sandy bed of the river near the spring; and granite, basalt, and a red schist resembling that so common in the diamond districts, occur in the neighbourhood; diamonds also are occasionally

* No sulphuretted hydrogen can be detected in the water of the springs running into the lake. The hot spring of Anhoni Simhoni, in the sandstone and basaltic district between the valley of Berar and the Nerbudda, I have found to contain sulphuretted hydrogen and muriate of soda, without lime.

† Journal of the Asiatic Society of Bengal, vol. ii. p. 397.

found. Other hot springs are reported to exist in this line of elevation; but that wild and little-known country, far removed from the residence of any European, must long remain in a great measure unexplored.

The facts stated in the preceding pages prove that the basaltic rocks, by which so much of Western and Central India is covered, are more recent than the sandstone and argillaceous limestone of the basins of the Pennar, Kistnah, Godavery, and of the mountains south of the Nerbudda; and that, notwithstanding the frequent occurrence of these rocks in a horizontal position, they have been subjected to violent operations, which have in many instances elevated the strata and remarkably altered the rocks themselves. It also appears, from observations made on the borders of the trap districts, and in other places where the primary rocks and the sandstones and limestones are not entirely concealed, that the basalt has burst forth from numerous fractures in these formations, probably simultaneously, although often forming insulated masses. It is possible, that more than one period of eruptive violence may have occurred between the era of the formation of the greenstone dikes, so common in the granitic districts, and the conclusion of the eruptions by which the fossils were entombed; but at present there is no proof of such having been the case; and all observers have considered the eruptions to have been contemporaneous; an opinion, to a certain extent, confirmed by the occurrence of the same fossils in very distant localities.

The sandstone and argillaceous limestone I have myself traced, from the neighbourhood of Nagpoor nearly to the junction of the Wurdah with the Godavery, bearing the same characters as in the vicinity of the fossil beds; and I have collected specimens of the same rocks at various places between this and Badrachellum and the diamond mines in the neighbourhood of the Kistnah. This tract, for 250 miles, is nearly an uninterrupted forest, and presents many difficulties in the investigation of its geological structure. Trap rocks and basaltic soil occur in many parts of the course of the Godavery, and granite of the usual character is occasionally met with. Dr. Voysey, who investigated great part of it with his usual accuracy, describes the sandstone as constituting a range of mountains 60 miles in extent, to the north-west of Badrachellum; and the surface rock 20 miles south of Ellore (near the alluvial plains of the Kistnah and the diamond mines), also at Mungapett on the Godavery, where I found silicified wood resembling that of Pondicherry.* Fossil wood was also seen by Mr. Geddes strewed

* Journal of the Asiatic Society, vol. ii. p. 402. The tenor of Dr. Voysey's observations in this place seem to show that he considered the "clay slate," in which he included the sandstone, to belong to the same formation as the limestone; a conclusion I had formed before meeting with his paper, and which has not been expressly stated in any of his writings yet given to the public.

over the country N.W. of this point, towards the junction with the Wurdah. Where the sandstone of the Godavery meets the granite to the west Dr. Voysey states that it can hardly be recognised as the same rock, consisting of a conglomerate containing quartz, felspar, and rounded pieces of granite resembling that of the eastern ghàts. The argillaceous limestone occurs in the same district, and is more widely distributed than Dr. Voysey supposed. He found it at an elevation of 2,600 feet above the sea, and exhibiting marks of great disturbance, dipping to the S.E., and at the summits of the hills intermixed with quartz rock.* Dr. Voysey considers these formations at the lower part of the Godavery to be the same as those of the Kistnah and Pennar; and in this opinion I fully coincide, although I have found the continuity of the sandstone and argillaceous limestone to be interrupted by a narrow band of granite, extending from the delta of the Kistnah to the granitic platform of the Deckan. Some of the hills, however, have caps of sandstone. In the present state of our knowledge it is difficult to form any correct notion as to the dip and direction of these rocks. Indications of derangement and elevation by the granite are, however, sufficiently apparent.

Sandstone and schists of the same characters, and associated with the same rocks, are also extensively distributed along the great tributaries of the Kistnah, in the Southern Mahratta Country, near the western ghàts, and a little to the south of the part of the basaltic district described by Colonel Sykes (Geol. Trans. 2nd Series, vol. iv.). The limits of this part of the formations have been but imperfectly traced. According to Dr. Christie's observations and my own, they are the same as those of the Cuddapah district.† The occurrence of sandstones and stratified limestones in this situation is a fact of great importance, which has escaped the notice of those who have speculated on the period of elevation of the great mountain chains of the peninsula. It was for this reason that I selected the line of section from Madras to Atchera, on the western coast, within the limits assigned by Colonel Sykes to the basalt, and near to which I discovered the sandstone *below* the escarpment of the western ghàts. (Section 2, map.) In the pagoda of the town I observed several quartzose sandstone pillars; and I discovered the rock itself forming a small range of hills to the south of the town, and dipping at a considerable angle to the N.W. The stone is similar to that of the hills, near the Chinoor diamond mines. The rock at the entrance of the inlet is laterite, having the appearance of horizontal stratification; and there are some indications of trap below it; but of this I could not obtain positive evidence. Colonel Sykes, however, states that the basalt occurs a little to the south at Malwan; and I

* The structure of the wood is beautifully preserved: it is coniferous. June 24th, 1839.

† Edinburgh New Philosophical Journal, 1828 and 1829.

found it at Colter, and other places to the north, underlying the laterite, at the foot and on the escarpments of the hills. These facts are sufficient to show that the elevation of the western ghàts in this part of their course was posterior to the deposition of the sandstones, which, for the present, must be considered as contemporaneous over all the districts described. I am aware of the uncertain nature of mineralogical characters, as characterizing different formations; but in rocks exhibiting such remarkable appearances and relations over such extensive areas, and when no organic remains exist in them, I do not think it wrong to place some confidence in the evidence they afford, more particularly in the south of India, where the rapid changes of formations, so common in Europe, are quite unknown.

The speculations of Elie de Beaumont on the age of these mountains is founded on negative evidence and analogies which appear to me to have little weight; nor can I consider the remarks of Dr. Benza, founded on his excellent researches on the geology of the Neilgherry mountains, as more conclusive. The non-occurrence of stratified rocks and of organic remains in a high granitic table-land affords no proof that these mountains have not been recently elevated; and the plentiful occurrence of ferruginous sandstone, containing brown coal, lignite, and mineral copal, at the foot of the Travancore mountains, show that these inferences have been too hastily drawn, when such gigantic generalizations were to be established.

Age of the Diamond Sandstone and Argillaceous Limestone.

With regard to the age of the diamond sandstone and argillaceous limestones, my own conviction is that they belong to the more ancient secondary, or even transition rocks; an opinion which is not at all contradicted by their frequent occurrence in horizontal strata, as they could not have been deposited in the situations in which they are now found. The facts I have stated will enable others to estimate the correctness of an impression founded on the structure, geological relations, and occasional nearly vertical position of the strata. On this subject I would express no decided opinion, but recommend an examination of the junction of these formations with the stratified and unstratified primary rocks, with a view to this question.

The sandstones and limestones of Bundlecund and Malwa correspond in many particulars with those of the south of India, and have been considered by all writers as belonging to the same formations. The sandstone, Major Franklin considers to be the same as the saliferous sandstone of England;* to which it has been objected, that the salt

* Geol. Trans. 2nd Series, vol. iii. part I.

diffused through the soil of Bundlecund may not be derived from this source, as it has never been discovered in that rock. I have also ascertained that salt occurs in all the formations of India, from granite to recent alluvium. I have, indeed, never met with a saline spring in the sandstone, but this I consider to be accidental, that rock being generally placed in inaccessible situations. I have, however, found thin seams of salt, interstratified with the upper schistose layers of the argillaceous limestone, in the immediate neighbourhood of a cliff of sandstone 300 feet in height, between the lower beds of which a similar schist was interposed. A more important objection to Major Franklin's opinion of the diamond sandstones belonging to the new red sandstone is, that in the peninsula this sandstone, throughout 800 miles of latitude and half as much of longitude, is *superior* to the limestone he has called "Lias." Nor can I find sufficient proof in his memoirs, or in other papers on the country between the Nerbudda and the Ganges, that this limestone reposes directly on the sandstone; and it is evident that no inference can be founded on its occurrence at a higher level in a country so much altered by denudation and the intrusion of eruptive rocks. But should it be hereafter found that the limestone in certain parts of Bundleeund does actually occupy a higher geological postion, the fact would not be conclusive against the diamond sandstones of the north and south, belonging (as everything indicates) to the same formation. I am indeed of opinion that the argillaceous limestone and the sandstone constitute only one formation, although I do not think that they should be spoken of as such in the present state of our knowledge. The basalt which has broken up and penetrated these rocks to the north and south of the Nerbudda is connected with the same system of trap rocks, and was probably erupted at a period much more recent than either of those to which the sandstones and limestones have been referred.

Inferences respecting the Fresh-water Fossils.

On the evidence on this subject afforded by the fossils imbedded in or covered by the basalt I shall now make a few observations. For the descriptions of the shells I am indebted to Mr. J. De Carle Sowerby.*

These fossils all belong to fresh-water genera, and to species which have not yet been discovered recent. I have not been able to obtain the seeds of Asiatic *Charæ*, nor the valves of any *Cypris* inhabiting the fresh waters of India. The shells, however, all differ from those inhabiting the rivers of the neighbouring country, as far as Mr. Sowerby and myself could judge, by comparing them with a collection of recent shells, which I made during a residence of several years at Nagpoor;

* See Plates 2 and 3, and Description.

nor do I think it possible that any of the larger shells could have escaped my notice, did they still inhabit the northern branches of the Godavery. Colonel Sykes, also, had the kindness to allow me to examine a collection of recent shells, made by him near the western ghàts, consisting of the same species as those of the Berar valley, and they are, of course, different from the fossils. I also failed to detect amongst them any of the shells contained in a large collection of recent land and fresh-water Testacea from Bengal, presented to the Zoological Society by Mr. Benson. It may, therefore, be inferred that the fossils do not belong to recent species.

Gyrogonites have not yet been observed in any deposit more ancient than the fresh-water formations of the basin of Paris. Cyprides occur in the tertiary strata, and in the Weald clay below the chalk, and perhaps in the Birdiehouse limestone of the Edinburgh coal-field. Of the other five genera discovered in these fossil beds, two have hitherto been found only recent or in tertiary deposits, viz. *Limnea* and *Physa* ; and the best characterized specimens of some of the others are referable to the same period. It is, therefore, extremely probable that the basalt in which these fossils are imbedded, and which has altered the rocks in which they occur, belongs to the tertiary epoch ; but to which period I fear we have not the means of forming any decided opinion. Though none of the species are recent, yet they are too few and in too ruinous a state to admit of any general conclusions ; although, from the very great number of individuals collected in various localities, without adding any fresh species, it is probable that nearly the whole which exist have been procured. But when the vast extent of the country occupied by the basalt is considered, and that a still greater tract was broken up or disturbed at the time of its eruption, it will not appear improbable that a rule, founded on the disappearance of marine shells in districts exposed to no such extensive causes of destruction of animal life, should not apply.

In the preceding pages I have described the fossils discovered by Mr. Geddes and myself in various parts of the Sichel mountains, and the Valley of Berar, extending through the great trap district for 140 miles ; and I shall now shortly refer to other localities at great distances from each other, where the same fossils have been found in similar rocks, buried under the basalt.

Other Districts of India in which similar Fresh-water Shells have been found.

Dr. Spilsbury discovered, eighteen miles from Jubalpoor, in an undulating plain studded with irregular masses of trap, blocks of "indurated clay," containing casts of fossil shells, for the most part siliceous, and

resembling those discovered by Dr. Voysey in the Gawilghur range.* At Saugor, nearly 100 miles to the north-west, reversed shells, stated to be exactly the same as those of Jubalpoor, were discovered by Dr. Spry in a bed of limestone, entirely surrounded by an amphitheatre of trap hills, in which a lower range of compact sandstone is included.† This fossiliferous limestone is covered by 17 feet of basalt, and rests on a coarse siliceous grit, under which basalt is again met with. In the same neighbourhood fine specimens of silicified palms are found. Jubalpoor and Saugor are situated to the north of the Nerbudda, in the great Vindya range; and in the same district fossil bones of mammalia occur in limestone capped by basalt. The drawings of the shells differ a little from each other,‡ but the fossils are stated to be the same; and, as far as Mr. Sowerby could judge, they do not differ from the *Physa Prinsepii.* The similarity was more obvious in other specimens left in India, and I have no doubt of their being the same. It is, however, desirable that the specimens themselves, in the Museum of the Asiatic Society of Bengal, should be compared, that the connexion of the northern and southern portions of the trap formation may be placed beyond a doubt. South of the Nerbudda, fossils are again met with in the mountainous country, north of the sources of the Taptee, at a place called Jirpah, near to which trap hills have broken through the sandstone. Dr. Voysey, in speaking of the heat of the steel furnaces of Nirmul, notices the occurrence of an "indurated clay" containing fossils at this place, but he gives no further information regarding them.§ In a small specimen of this rock, Mr. Sowerby recognised the *Paludina Deccanensis*, and a portion of a larger shell, probably the *Physa Prinsepii;* and the matrix is the same as the fossiliferous "indurated clay" from Gawilghur; it also much resembles many of the varieties of chert in which the Berar fossils are found. The third range of hills has been described by Dr. Voysey under the name of the Gawilghur mountains, and it forms a very remarkable feature in the physical geography of Central India. In this lofty basaltic range Dr. Voysey discovered fossil shells, the situation of which he has accurately described;|| but as his account of them has been so far misunderstood as to induce Mr. Conybeare to state that they occur in "lias-like beds,"¶ and Colonel Sykes in a recent deposit,** it is necessary to mention that they are found in mountains in great part composed of basalt resembling that of the Giant's Causeway, but containing, more frequently, crystals of olivine, of basaltic hornblende, and carbonate of lime. This rock passes into a wacké, having

* Journal of the Asiatic Society of Bengal, vol. ii. p. 205.
† Ibid. pp. 376, 639.
‡ Ibid. p. 583, Plate 20.
§ Journal of the Asiatic Society, vol. i. p. 247.
|| Asiatic Researches, vol. xviii. p. 187.
¶ Report to the British Association, 1832.
** Geol. Trans. 2nd Series, vol. iv. p. 426.

every variety of structure and induration known amongst trap rocks, or into what has been called stratified basalt, from the parallelism of its planes, "the summits of many of the ravines presenting a continued stratum for many thousand yards."*

Ascending from the Taptee river, Dr. Voysey† observed a group of basaltic columns, and near the summit of the flat table-land of Jillan he entered a pass presenting a perpendicular section, above the road, of 30 feet, and below it a rapid descent of between 40 and 50. The lower part of the section, as well as the pathway, is composed of wacké, and "lying on it is a stratum of earthy clay of different degrees of induration, 20 yards in length and about 2 feet thick, containing a great number of entire and broken shells," which are much compressed, and do not effervesce with acids. Some of them completely commix with the matrix. This bed of clay possesses all the characters of a stratum, which Dr. Voysey says seems to have been depressed by an overlying mass, 15 feet thick, of the nodular basalt or wacké so common in these hills. The vertical fissures, which are so "remarkable in trap rocks, are prolonged from both the upper and lower rocks, into the shelly stratum, although there is no intermixture of substance." The stone in which these fossils occur is similar to that of Jirpah, and of many of the specimens from the Sichel range and the valley of Berar; and the casts and fragments of the shells resemble those of the Paludinæ and other shells of that district. Between these mountains and the Sichel hills, the great valley of Berar is included, but the two ranges closely correspond in the nature of the soil and rocks, and in their fossiliferous beds. They are not, however, exactly parallel; nor do I think that we are justified in classing them with the Vindya range to the north of the Nerbudda, or with the range which separates the valley of that river from the valley of the Taptee.

It is evident, from the same fossils being found in all these ranges, several hundred miles distant from each other, and from the same secondary rocks being broken up and altered, that the basalt of which they are principally composed was, in part at least, erupted at the same time; and that the western and eastern ghâts must have partaken in this great movement.

Shells, probably of the same genera, were also found by Dr. Voysey in the insulated basaltic hills of Medcondah‡ and Sivalingapah, which

* Dr. Voysey, Asiatic Researches, vol. xviii. p. 127.

† Asiatic Researches, vol. xviii. p. 192, and Journal of the Asiatic Society of Bengal, vol. ii. p. 304.

‡ In a specimen of this chert in the Geological Society's Museum, I have found a gyrogonite of the same kind as those of Nirmul, and halves of a species of *Cypris* associated with shells. June 24th, 1839.

rest on the granite of the Deckan, south of the Godavery, and are probably connected with the southern part of the great trap district, and the hills of Bicknor Pett and Nugger shown in Section 1, Map. The fossils are imbedded in the basalt, in a siliceous rock containing lime, and corresponding in specific gravity, chemical composition, and appearance to the fossiliferous cherts of the Nirmul Hills. Sivalingapah lies considerably to the west, but nearly in the same latitude as Nirmul.

The only other locality where fossil shells have yet been discovered, within or near the great basaltic district, is five miles south of Rajahmundry, a large town on the Godavery, a little above the alluvial plains of its Delta.* They occur in some small hills ranging nearly W. and E., and composed of conglomerate and red sandstone supporting wacké, overlaid by limestone containing shells, which is again covered by basalt. The shells are in the best condition in the upper part of the limestone; of many only the impressions remain, but the oysters, which are the most abundant, are well preserved. The basalt and some specimens of the chert, jaspers, &c. from these hills, presented to me by Dr. Benza, resemble the varieties found with the fresh-water shells of the Sichel range, and the hills in which they occur, having the same direction, are probably connected with the eastern termination of that range. They are evidently associated with the sandstones of the diamond districts to the north of the Kistnah, and with the continuation of the eastern ghàts; thus confirming the opinion above expressed, of these mountains being of more modern elevation than is supposed by some geologists. It is impossible to separate the western ghàts from the eastern in any theory that can be formed, as they diverge from the same point, support the same table-lands and the same stratified rocks; and where these mountains meet at the Neilgherry Hills, the hornblende schist has been noticed by Dr. Benza to dip in opposite directions from the eastern and western mountains.

In the Journal of the Asiatic Society of Bengal, vol. iv. p. 565, and Plate XLVIII., fossil shells are figured, which bear considerable resemblance to some specimens of Unio from the Sichel Hills, but not sufficiently to identify them. They form part of the Dadapoor collection of Sub-Himalayan fossils, so ably investigated by Lieutenants Baker and Durand, and are stated by Mr. Prinsep, in a note, to be identical with specimens collected by Colonel Burney with the bones of the Mastodon, &c. in Ava. He adds, that they probably belong to the large and thick species of *Cyrena*, noticed by Professor Buckland as occurring in a blue and marly clay near the locality of the fossil bones collected by Mr. Crawford (Geol. Trans. 2nd Series, vol. v.); but I found the spe-

* Dr. Benza on the Neilgherries.—Journal of the Asiatic Society of Bengal, p. 435, August 1835.

cimens of these shells in the Society's collection to differ both from those of the Sub-Himalayahs and of Central India.

Mr. Pentland, in the same volume of the Geological Transactions, makes the following observations on Indian tertiary deposits: "How far the same formation may be prolonged in a southerly direction along the peninsulas of Malacca and of Hindoostan it is impossible to say; although we possess proofs of its existence at Madras, where it contains the same species of shells as on the Brahma-putra, and at Pondicherry, where it envelopes the great masses of silicified wood found near that city." (p. 394.) The formation on which Madras stands is, however, erroneously referred to the tertiary epoch, being a recent alluvium, accumulated by the joint action of the rivers and breakers, and containing the same shells as now inhabit the mud of the salt-water inlets and sea-shore of the Carnatic.

With regard to the age of the silicified wood of Pondicherry, no facts have yet been ascertained which can justify any conclusion. It is, however, to be hoped, that a gentleman familiarly acquainted with the tertiary and volcanic rocks of Greece and Italy will soon communicate positive information regarding the geological relations of the sandstones containing the silicified trees and the fossil shells,* the conical hollows, obsidians, and other indications of volcanic action said to exist in that neighbourhood.

Relative Age of the Laterite and Trap.

I shall conclude this paper by one or two remarks on the relative age of the Laterite and Trap. Dr. Babington† and Dr. Christie had observed this rock, both below and above the ghàts in the latitudes of Seringapatam and Goa, and I have traced it in the deep and narrow valleys of Coorg, at various heights, from the level of the sea to several thousand feet above it; but as in all those places it rests on syenite or other granitic rocks, from the decomposition of which, *in situ*, there is much reason to suppose that this remarkable formation is derived, no inference as to its age can be drawn from these facts. At Colter, however, and other places on the coast of the great basaltic district, it rests on the basalt, forming the summits of the hills, or an external layer over the trap which constitutes the body of the hill. This superposition is exhibited in ravines passing through the laterite, or where that rock has thinned off so much that it can be separated from the basalt below, which has most commonly a stratified arrangement, often highly inclined and parallel to the precipitous face of the hill. It has also been observed

* The shells I have seen differ from those of Central India.

† Geol. Trans. 1st Series, vol. v. p. 329.

above the ghàts, and in the table-land of the Deckan, between the Godavery and Manjera rivers, resting on basalt; it is, therefore, probable that the trap has been protruded from below, since the laterite assumed its present form. It would be improper, in this place, to enter into any details regarding a formation which extends over much of the Malay peninsula, Ceylon, the Coasts of Coromandel and Malabar, and Central India. In different portions of these vast countries, several varieties of this rock are met with, well deserving of attention, yet its general character and composition is the same over 30 degrees of longitude and 20 of latitude, and nowhere is any proof to be found of its being of volcanic origin,* or the equivalent of certain European rocks, as supposed by Elie de Beaumont. Under the name of laterite, however, very different rocks have been included; such as the ferruginous clays and sandy beds underlying the alluvium of the Irawady, near Rangoon, and a ferruginous conglomerate now forming in many places from decomposed and reconsolidated laterite or syenite, and containing fragments of granite, and occasionally enveloping a recent land shell.

Besides these, a rock, apparently of igneous origin, has been occasionally confounded with laterite, and in the diamond districts is known to the natives by the same name as is applied to that rock in the Mysore. The thinner strata of the diamond sandstone of the Pennar have been observed to be bent in a remarkable manner by the intrusion of this rock; and in other instances it had apparently escaped in a semifluid state between the joints of the larger tables, carrying with it fragments of the sandstone, whose angles are so well defined that I thought I could trace the very spot from which they had been broken off. Notwithstanding these appearances, the character of the rock differed so much from any varieties of basalt I had then seen in India, that I hesitated about referring it to the trap family, till I had seen varieties of a red wacké much resembling it, constituting part of the basaltic mountains of the island of Salsette. It is in a substance of this kind, interstratified with sandstone, that Tavernier describes the diamond mines of Beejapoor to have been worked in former times. The transitory nature of the political divisions of this part of India, and the decay or desertion of many towns and villages, have hitherto prevented the identification of these mines; but enough has been said to show the importance of caution in reasoning on individual facts, relative to one of the most singular and extensive formations anywhere to be found.

* Calder, Asiatic Researches, vol. xviii. Conybeare, Report to British Association.

Note.

The fresh-water shells described in the preceding pages must have inhabited sheets of fresh water of which no traces can now be discovered, in the configuration of the mountainous tracts in which they for the most part occur. No natural lakes exist in these districts, nor could shells have accumulated in such quantity in rivers similar to those which now intersect the country. It may, however, be supposed that the sandstone and limestone rocks of Berar had once a position similar to that which the same rocks now occupy in the basins of the Kistnah and Pennar. Voysey describes these rivers as passing through the Nulla-Mulla range by gaps or fissures "which have been produced by some great convulsion, which, at the same time that it formed the beds of these rivers, gave passage to the accumulated waters of some vast lakes situated near the outlets." "The tortuous course of the Kistnah is bounded for upwards of 70 miles by lofty and precipitous banks, which in some places rise 1,000 feet above its level, the opposite sides of the chasm corresponding in an exact manner. Ravines of this description are not unfrequent all over the range, and the exact correspondence of their salient and re-entering angles, together with the abruptness of their origin, totally preclude the supposition of their being hollowed out by the action of running water."* Such seems also to have been the case where the Pennar passes through a narrow gorge in the Gundicottah sandstone hills. Through the upper part of its course, this river flows over flat country covered with alluvial soil, at right angles to the hills; but it finds an exit through them by a fracture in the wall which in former times had apparently dammed up its waters. The strata have been much disturbed, probably by the eruption of the basalt, which is seen at the foot of the sandstone hills on the opposite side of the valley, from which the Gundicottah range appears to have been separated. Section 2nd, Map. It should, however, be stated, that ravines formed in this sandstone, by the action of the streams now flowing in them, exhibit abrupt precipices, the opposite sides of which correspond to each other as Voysey has described.

The Sections accompanying this paper were constructed by Captain Smith, of the Madras Engineers, F.R.S., from information contained in my notes made during several journeys in the lines represented, and from some published papers. The information is by no means com-

* Asiatic Researches, vol. xv. pp. 123, 124.

plete, but, I believe, it will be found to be correct as far as it goes. In consequence of the great length of the lines to be represented, and the comparatively moderate height of the hills, it would have been impossible to have given the different formations of sufficient size to have been seen in a distinct manner without great distortion of the strata, had the whole distanee been represented. Breaks, therefore, have been introduced, representing the continuance of the same rock for the number of miles specified in each instance. In the Baulpilly valley and in some other localities (Sect. 2) the summits of the hills are almost inaccessible, and it has consequently been impossible to represent them as they occur in the exact line of section. I have, therefore, been content to exhibit the strata as they occur at their bases, with the exception of a few of the hills which have been more carefully examined, and which correspond in appearance to those which are as yet unexplored.

Seetion 1st passes from the Bangnapilly diamond mines to the valley of the Nerbudda, with the view of connecting Section No. 1, across the peninsula, with a line running north and south through its centre; and which might easily be continued to the Himalayah mountains to the north, and Ceylon to the south.

Note to line 7 from the top of Page 9.

"In a specimen in the Geological Society's collection, taken by Dr. Voysey from a '*greenstone dike*' passing through granite, at Guntoor south of the Kistnah river, olivine is diffused amongst the other constituents of the rock." June 25th, 1839.

EXPLANATION OF THE MAP AND SECTIONS.

The Map is intended only to assist the reader in following the description contained in the paper, and to exhibit a general view of the distribution of the rocks occurring between the Taptee and Pennar rivers. However imperfect this slight sketch confessedly is, it is hoped that, by embracing almost all the information yet obtained respecting this extensive region, it will correct the erroneous opinion entertained by many of the simplicity of the geological structure of the South of India, and afford a nucleus around which additional and connected observations may be gradually arranged.

It has been found impossible to employ more than two colours for granite, gneiss and mica, chlorite and hornblende schists; for although many good observations have been made on the distribution of these rocks in certain parts of the country, yet the boundaries have not, in general, been clearly distinguished, nor is it always easy to do so. Where the stratified primary rocks prevail more abundantly than granite, a purple tint has been employed.

The diamond sandstone and argillaceous limestone appear to constitute parts of one formation, and it has therefore been thought better not to distinguish them in a map of such small dimensions; though an attempt to do so has been made in the sections. The laterite is introduced only where it occurs resting on basalt, at Beeder in the Deckan; its limits are unknown. Near Nellore, a nearly similar formation rests on the primary rocks, and is probably formed from their decomposition *in situ*.

The trap is represented the same colour as in the illustrations to Col. Sykes's Memoir on the Deckan (Geol. Trans. vol. iv. Pl. XXVI. 2nd Series), to enable the reader to connect the district represented in Col. Sykes's map with that contained in the accompanying map.

The Section, fig. 1, at the top of the Map, extends from Bundlecund, beyond the north boundary of the map, to the Bangnapilly diamond mines, situated between the 15th and 16th degrees of north latitude.

Section, fig. 2, extends across the Peninsula from the coast near Atchera (lat. about 16°) to Madras.

EXPLANATION OF THE PLATES.

Plate I.

Fig. 1. Section of the Bangnapilly Diamond Mines.

Fig. 2. Section of the Lonar Lake and surrounding rocks.

Plates II. & III.

Organic remains collected by Mr. Malcolmson, and described and engraved [*in orig.*] by Mr. James de Carle Sowerby.

Fig. 1. *Chara Malcolmsonii.* Oblong, spheroidal, with 10 ribs; three of the ribs are produced at the apex. Natural size and magnified.

This capsule is composed of 5 tubes, each of which is curled twice round. The figures represent a cast of the interior, the tubes being split down, and the outer halves broken away and left in the chert. The specimens are silicified, and constitute almost the entire mass of the rock in which they occur, associated with *Physæ* and *Paludinæ*.

Fig. 2. *Cypris cylindrica.* Twice as wide as long, almost cylindrical; front very slightly concave; the outer surface, which is very rarely obtained, is punctured.

Fig. 3. *Cypris subglobosa.* Subglobose, triangular, inflated; front concave.

The outer surface of this crustacean is punctured as in *C. cylindrica.*

Both species occur abundantly in grey chert, with the *Unio Deccanensis* and other shells; and in various specimens of chert and indurated clay containing *Gyrogonites, Paludinæ, Physæ,* and *Limnei,* from the Sichel hills. The fossils are converted into calcedony.

Figs. 4 to 10. *Unio Deccanensis.* Transversely oblong, rather compressed; margin internally waved; shell very thick; surface finely striated. Fig. 6 is in limestone from the northern descent of the Sichel hills; the others are in chert from Munnoor. Natural size.

This species has often a ridge, which bounds the posterior portion, and is variable in size and elevation; it is most conspicuous in the limestone specimen, fig. 6, and in a cast in chert from Munnoor, fig. 7. Fig. 8 is possibly a very young individual, before the margin had assumed its wavy form. Fig. 9 is from a part of a group of many individuals of nearly one size badly preserved in the same limestone as fig. 6; but as they are regularly oval, and do not show a waved margin, they may belong, as well as fig. 10, which is in grey chert from Munnoor, to a species distinct from *U. Deccanensis.* Some flattened specimens from this limestone are 2½ inches broad.

Figs. 11 and 12. *Unio tumida.* Transversely obovate, smooth, gibbose; posterior extremity rather pointed; beaks near the anterior rounded extremity. Natural size.

The section of the two valves united is regularly heart-shaped. The shell is rather thin, and it has something of the contour of *Cyrena*. It occurs in the same limestone with fig. 6, and the substance of the shell is replaced by calcareous spar, which cannot be broken so as to show the hinge.

Fig. 13. *Limnea subulata.* Subulate, elongated, smooth; spine equal in length to the body; whorls five. In a nearly white, soft, siliceous stone from Munnoor and Chicknee. Natural size.

Figs. 14, 15, and 16. *Physa Prinsepii.** Ovate, rather elongated, smooth, spire short; body-whorl largest upwards. Fig. 16, in a soft siliceous stone from Munnoor. Fig. 14 in chert from Munnoor, and fig. 15 in chert from Chicknee; the drawing represents the shell as wider than it is. Many of the specimens are crushed. The largest, fig. 15, are 2½ inches long and upwards of an inch broad. Natural size.

Figs. 17 to 19. *Melania quadri-lineata.* Subulate, whorls about eight, with four striæ upon each; aperture nearly round. Fig. 17, in grey limestone from the same locality as 6 and 11. Fig. 18, in softish chert from Chicknee, associated with *Physa Prinsepii.* Fig. 19, in fine reddish grey chert, protruding from basalt near Munnoor, appears rather shorter in form than the others, but the spine is not perfectly exposed or entire. Natural size.

Figs. 20 to 23. *Paludina Deccanensis.* Short, conical, pointed, rounded at the base; whorls 5 or 6, slightly convex, aperture round. Fig. 21 is in chert from Munnoor; and figs. 20 and 22 in indurated clay from between Munnoor and Hutnoor, the cavity of the shells being filled with calcedony. The young shell has a slight carina shown in fig. 20. Fig. 23 appears to be a crushed specimen; it is in laminated, indurated clay, Munnoor. This shell occurs, with *Physa Prinsepii,* in a beautiful green siliceous mineral at Munnoor; at Chicknee, and at the bottom of the Nirmul pass. All the specimens natural size.

* Mr. Sowerby has, with much propriety, named this fossil after Mr. James Prinsep, F.R.S., and Secretary to the Asiatic Society of Bengal; to whom Oriental science and literature are more indebted than to any other individual.—J. G. M

ERRATUM.

For "Plate I." p. 17, *read* "Plate II."

Extracts from Dr. Voysey's *Private Journal, when attached to the Trigonometrical Survey in Southern and Central India.**

From Secunderabad to Beeder.

Saturday, 9th January 1819.—I quitted the Cantonment, Secunderabad, at three o'clock. I met Major Hopkinson at the bund of the tank, who was making or repairing the road destroyed by the overflow of last season; he was in the act of directing the removal of a large block of the greenstone. He told me that the vein was continued beyond the tank in a northerly direction, but that it could not be traced further south; also that the large vein crossing the road to the Residency was continued in the same direction to Hyauttnuggur twelve miles distant. He mentioned the singular discovery of cairns and Druidical circles by W. P. of the Artillery, one of which had been opened lately of a curious formation, and several bones had been found in it. The granite continues to wear exactly the same aspect here and on the road we have travelled from Secunderabad, the loggan stones and tors being very numerous.

Sunday, 10th January 1819.—Halted the whole day at Chinchawalee ka Durga, and in the afternoon visited the tombs of Golconda,—large cupolas supported on square pilasters of granite of an extraordinary length; some of them were at least 20 feet high, of solid stone. The tomb is in the centre of the hall, formed by the cupola, and is made of greenstone. Of this stone we discovered a vein about 10 feet wide and running east by south, the same direction as those in Hyderabad; the sides were composed of granite, intermixed with the greenstone, which affected the form of rhomboidal blocks, and was penetrated by quartz veins. From the top of one of the tombs we had a very fine view of the fort of Golconda, which is not so strong as it is supposed to be. Granite. No diamonds. The characteristics of this country, and striking ones they are: loggan stones and tors of the most grotesque appearance, generally smaller than their support or pediment, and in many instances piled together by threes; their origin I shall hereafter speak of:—tanks of large dimensions, varying from twenty to thirty miles in circumference, formed by dividing the bed of a natural lake formed during the rains into two parts by a large mound or bund, through which several locks suffer the water to escape, as it is wanted to fertilise

* Reprinted from the Journal of the Asiatic Society of Bengal, vol. xix. 1850, p. 201 *et seq.*

the other half of the bed, converted into paddy fields;—the trap or greenstone running twenty miles E. by S., of which I have seen three miles; this stone is used for lingams and gods by the Hindus and for tombs by the Mahomedans.

Monday, 11th January 1819.—We travelled through a country similar in all respects to the one we had quitted, except that the granite tors assumed a still more grotesque appearance as we advanced, until within two miles of Puttuncheroo, when the granite suddenly ceased to be visible, and a fine plain of alluvial soil was spread out before us, covered with trees and bearing the strongest proofs of great capability for cultivation.

Tuesday, 12th January 1819.—The country between Puttuncheroo and Begumpett, on which the village is built, consisted of the same fertile soil and plain, bounded on the east and west by low granite hills still preserving their peculiar features, when, on our arrival at Begumpett, the granite suddenly re-appeared in our path and formed the hill on which it stands. On descending we found a stiff bluish clay, which continued to the place of our encampment, Susdanuggur, on the borders of a tank.

Wednesday, 13th January 1819.—We travelled through the same plain; low granite hills making their appearance until we nearly reached Wondole, when quartz rock, forming considerable elevations, running in N. and S. direction; this rock continued for a mile and a half, and then disappeared two or three hundred yards from Jogypett, the place of our encampment. There the rock rises highest, perhaps 50 feet. The quartz appears to have been once covered by an iron clay deposit from the quantity of pisiform iron ore found on it, and from that formation being found in the ravines and rents at the sides and bottom of the hills.

Thursday, 14th January 1819.—We passed through Jogypett, and crossed a plain about seven miles in breadth, between the quartz rock and the hill on which Colonel Hampton's flag was fixed; the sides were covered with angular and rounded masses of a rapidly decomposing greenstone or hornblende rock, on breaking which the grey colour of the decomposing surface was found extending into the black crystalline rock for about two lines. The soil formed by its decomposition was very rich, and retentive of moisture. The form of the surrounding elevations was nearly similar, and had nearly the same N. and S. direction. The stone had no perceptible effect on the magnet.

Monday, 18th January 1819.—We quitted Tadmanoor for Jogypett. I had a better opportunity of observing the scattered lumps and masses of granite which are strewed without order on the plain at the foot of the quartz rock. I observed no difference in its structure from that of Hyderabad. On descending the hill I passed, just before the sun rose, through a stratum of air in which the evaporation was rapidly going on,

producing a very cold sensation. When I came to the bottom, as I had gone faster than to allow the inferior stratum to be affected by the same cause, the warmth was very agreeable, but, as I could go no lower, it speedily became cold as before, until the sun rose and counteracted the effect of the evaporation. I forgot to observe that the quartz rock is crystallized in rhombs, some of the angles of which are very perfect.

Tuesday (*Mungul*), 19*th January* 1819.—We crossed the quartz rock, which is not above three hundred yards in breadth, and, on descending into the plain watered by the large tank of Jogypett, soon met with lumps and masses of granite, which gradually increased to the river Manjira, of which it formed the banks. On crossing the river, now about its medium height, we observed with surprise veins of white granite passing through the syenitic granite, which forms its banks. The rock containing these veins is much more susceptible of decomposition from the hornblende which it contains than the veins of red and white granite, and the appearance produced was like a fretwork, when the broad surface of the rock was exposed; when an edge was left to the action of the atmosphere it was in small diagonal ridges.

This formation appeared confined to a space of a few hundred yards only on the right bank of the river.

It is worthy of remark that this river, after we crossed it at Begumpett, takes a considerable turn to the N., and that its bed no longer contains calcedonies there found in it. The mud, however, is the same, and appears to be that rising from the decomposition of the trap rock of Tadmanoor and elsewhere. After passing some elevated minor granitic hills we pitched our tents on the borders of a lake at the foot of the station Suldapoorum.

Wednesday, 20*th January* 1819.—The mixture of granite and syenitic granite extends to this place, as I observed masses of the syenitic granite imbedded in the former near my door; it reminds me of the same appearance at Teeperty, near Neelgondah. As I have specimens, I shall have an opportunity of comparing them.

Thursday, 21*st January* 1819.—About half way up the blocks of granite disappeared, and the paths presented the decomposing trap rock of nearly the same nature with that of Tadmanoor hill; its decomposition forms the same rich soil as on that hill; I found amongst it specimens of a substance intermediate between heliotrope and hornstone. From the top I counted thirty-three lakes, and should have counted more had the horizon been clear; the hill is not above two hundred feet in height; my barometer fell $\frac{2}{10}$ inch. The neighbouring mountains were slightly elevated above us, and their direction and form nearly that of the one we were on, N. and S., and round backed, with two or three slightly conical and more elevated summits in the range; in one

instance a range of low hills appeared to cross diagonally, indeed the direction of all was very indistinct and most commonly curvilinear.

Friday, 22nd January 1819.—For several miles after quitting Suldapoorum, I passed through a beautiful forest of teak, mango, *Ficus Indica*, tamarind, and other fine trees and shrubs mostly leguminous; the soil was partly granite and partly decomposing greenstone, but wherever rocks were visible they were invariably granitic. At a small village situated on an immense divided mass of granite a trap vein (primitive greenstone) crossed my road, running E. by S.; another about two miles further became visible, of larger dimensions, and was lost in the jungle. In a short time we were surrounded by granitic rocks with the same features which distinguish those of Hyderabad; huge masses with a concentric lamellar structure, loggan stones, tors, &c. but with a large quantity of detritus at the feet.

In the alluvium at the foot of the pass to Chittial was found a large breccia containing handsome specimens of amethyst quartz, accompanied by quartz, and cemented together by a siliceous sand, strongly impregnated with iron.

Sunday, 24th January 1819.—I gained the top of the hill after breakfast, and on my way found a considerable quantity of earthy brown and red ironstone lying scattered in the ravines and in the spaces between the granite rocks. I had no means of judging whether it formerly belonged to any formation such as the iron clay, but it certainly resembled that found in it.

Monday, 25th January 1819.—The ranges of hills appear to run principally N. and S. from to the east of north. As I descended I found a substance resembling calc tuff, in quartz, in a ravine lying on the surface, and apparently brought down by the rain from higher ground. I rode to Maidurh and round the hill on which the fort is seated; it resembles very much that of Golcondah; I passed a river running from west to east, and some strange tors and loggan stones.

Tuesday, 26th January 1819.—The road lay this day through a tolerably rich country, whose soil was of the black argillaceous kind arising from the decomposition of the transition trap, although, on advancing, without apparently changing our level, we met with the old granitic sandy soil, which is that of Ringumpett; and in its neighbourhood, where our tents are pitched, is a large grained granite with very handsome bluish grey felspar. I forgot to observe that the forms of the granitic rocks were more varied than I had yet seen them, forming every description of loggan stone and tors that can be conceived.

Wednesday, 27th January 1819.—The soil alternated from the black cotton soil, as it is called, to the sandy granitic, and the only rocks we saw in this extensive plain were granitic in small lumps and masses.

As we approached the river Manjira they were profusely spread on its banks and in the middle of its stream; here and there in its bed we observed small pieces of calcedony and cornelian. About three miles from our station, Ringumpett, I observed a very small-grained reddish granite, much used in the buildings of the village.

Our station was on the transition greenstone, differing in no respect from that of Tandmanoor,—the same black thirsty soil covered with the *Poa cynosuroides* (Kusa grass), also the *Semicarpus anacardium* and *Butea frondosa*. At a lower part of the hill due east from the station I observed in a stone, different from any other I had previously seen, several turritulites and bivalves. The stone is of a bluish grey colour, alternating from that to a blackish grey, containing transparent spots of stalactitic silica; its fracture is for the most part conchoidal, even with sharp edges it is hard, easily frangible, and specific gravity about 2·0. I have since found, in another part of the hill nearly due north from the station, large nodules of corroded and vesicular flint, and masses of the former stone passing into flint; some of the masses were a foot and a half in diameter. I also, in nearly the same direction from the station, at the distance of half a mile, saw the transition trap laid bare; it affected the columnar form, and was everywhere split and divided, without any appearance of stratification; in some cases I found on the surface concentric layers rapidly decomposing, enabling me to remove two of its coats.

Friday, 29th January 1819.—I went this day to the southward and westward, as I had previously been to the other quarters of the station. The cultivation has evidently extended all over the hill, fully accounting for the smallness of the shrubs and trees on it; ravines proceed in every direction from the top, forming in the rainy season large torrents, supplying the Manjira with the mud which it then deposits on its banks. In the lower grounds I saw wheat, cotton, ricinus, and linseed in cultivation and in flourishing crops. We had scarcely arrived at the bottom of the hill and about half a mile from the first village, when the granite appeared in an abrupt part of the road; near its first appearance we found precisely the same mixture which I have twice before noticed, viz. at the Manjira and Repurlah; near it was a bed of meerschaum. The granite, with its customary attendants in the shape of loggan stones and tors, soon succeeded, with here and there masses of greenstone rolled and scattered without order. The jungle prevented me from tracing their origin. In the evening I visited the fort, and saw at least a radius of thirty miles of the surrounding country; we were still in the vast plain, but now more broken in upon and diversified with rocks of granite. This is now redder, and contains veins of a still redder granite. It has also less of the appearance of concentric layers, and has a

more stratified look. The fort is miserably dilapidated; we were admitted without the least ceremony. The country appears destitute of springs, and depends entirely on the rainy season and a few rivers for its supply of water.

Sunday, 31st January 1819.—In the evening I observed in the banks of a small nulla, dry in most parts, and containing only a muddy water tasteless of any saline impregnation, an incrustation of carbonate of potash, from and apparently by the decomposition of the felspar of the alluvial* granite of which its sides were composed, acidified by the atmosphere.

Monday, 1st February 1819.—A short march from Sauhrampett to Bachapilly; the granite continues to be red and of a small grain; about half way a vein of greenstone passed the road. After breakfast I ascended the hill, which has a fine prospect in a southerly view bounded by a range of hills running east and west; their outline was rather different from those I have been amongst for some time past, being more peaked; the Manjira, taking a N.W. direction, is in the plain between. The mountain, or rather hill of Bachapilly is almost insulated, and may be seen on all sides at several miles distance, although not 200 feet in height. It consists almost entirely of granite in large irregular masses piled one on the other without order.

Tuesday, 2nd February 1819.—I left Bachapilly this morning for the river Manjira, its nearest approach being about four miles E.S.E. of the hill. The road lay through jungle, with heaps of granite at intervals in hillocks, and irregularly strewed over the ground; two miles from the encampment the road was crossed by a primitive greenstone vein taking its usual direction. On arriving at the river I found its banks and bed lined and filled with granite; on the right bank the black alluvium was thirty feet above the level, and perfectly horizontal on the top: the bed consisted of granitic sand, a few pieces of calcedony not very frequent, and a few shells of the same species I had previously found on crossing it first.

I should have observed that I saw magnetic iron sand mixed with the mud on the bank of the river; also in a stream which emptied itself into the river, a trace of the efflorescence of carbonate of potash. Our encampment is not above the level of the banks of the river, there being no difference in the barometer observed at each place.

Wednesday, 3rd February 1819.—The hills have no regular course or direction, one of the proofs of which is that the river runs in the midst of them.

Thursday, 4th February 1819.—I saw also near the village of Bacha-

* So in original, *diluvial* is probably intended.—Eds.

pilly some singular veins of granite rising through a greenstone or syenitic greenstone, very similar to what I had before observed on the banks of the Manjira: the veins, having resisted decomposition much better than the containing rock, remained projecting two feet in some instances. It is remarkable that a shift of the veins had taken place: the granite vein was sometimes white, sometimes red, like that at the Manjira; the course of what we could discern of this formation, which lay in a field formerly in cultivation and over which the jungle was spreading, was E. by S. Visited the Bears' Rocks, a granitic elevation of thirty feet, distant E. by S. from the station about 400 yards. Its base consists of a large grain containing red felspar, white compact ditto, and hornblende, forming altogether a beautiful stone; through this mass a vein of syenitic greenstone, differing in width from three feet to a few inches, runs for about fifty feet; this is again crossed by veins of a finer granite nearly resembling that higher up, which is in large blocks apparently placed without order, but an eye accustomed to these rocky elevations, almost peculiar to this country, discerns in these masses the remains of a concentric coat of granite. The remains of strata filled with these granitic veins are very common between.

Friday, 5th February 1819.—On our road through the plain the same kind of granite to which we had been so long accustomed was frequently seen in irregular masses. Two miles from Bachapilly we crossed a small nulla running in the direction of the Manjira. Immediately before entering Polelum a large deposit of quartz rock running E. and W. about half a mile, resting on granite; it was of the same description as that at Jogypett. Our road then lay through a plain of black cotton soil, when, after a tedious journey through a thick jungle, in which nothing was to be seen excepting masses of granite, and now and then lumps of greenstone, we began to ascend a hill composed of greenstone, having the same characteristics as that of Tandmanoor, containing foliated zeolite in abundance and calcedony lying loose in the ravines, and on its surface high Kusa grass (*Poa cynosuroides*).

Sunday, 7th February 1819.—I quitted the hill with Everest early to go to Kowlass. We descended one of the ravines so common on these hills and soon came to the usual kind of granite, but could not observe the junction of the strata; we again began to ascend by a very long road, until the junction between the trap and granite was very distinct, and on looking around us each of the numerous elevations in sight appeared covered with the same kind of trap resting on granite. It is worthy to remark that many trees on the hill are destitute of leaves, whereas in the valleys and ravines they appear to preserve them late in the season. We now began to ascend the hill on which the fort of Kowlass stands, in which there is nothing externally different from that

of Medenkah Golcondah; the fort and basis of the hill are of granite, both red large-grained, and grey small-grained; on its northern side and near the summit a very considerable vein of greenstone crosses the path, running E.S.E. and W.N.W.; its northern or upper edge is well defined and consists of greenstone porphyry, containing both crystals of felspar and smoky quartz in the upper part of the vein, but lower down the hill the stone is a coarse greenstone very subject to decomposition, which takes place in a concentric manner and very similar to that of the hill of Boorgapilly, which is more secondary and contains zeolites; its lower edge is less well defined, and, instead of being bound by the granite as on the other side, it is spread for several yards over the granite, lying directly upon it: the breadth of the whole is from about 40 to 50 feet; its length we had it not in our power to ascertain. After my return I visited the village of Boorgapilly, the environs of which consist of a very rich soil formed by the decomposition of the trap; in which soil, where it has not been disturbed, the zeolite has been re-crystallized in silvery plates.

Wednesday, 10*th February* 1819.—We crossed a nulla after descending the hill of Kowlass, running east to Manjira. We passed through a large plain of the black cotton soil and arrived at Beechicondah, through a pass of granite rocks in which were many loggan stones, and angles were taken. I reduced the temperature of Fahrenheit from 88° to 59°, at half past three o'clock P.M. The hill or hills are composed of red syenitic granite, very similar to that at Bachapilly, though of a smaller grain. I had an opportunity of observing the communication between this plain and the one which it follows. The whole is flooded during the rainy season, and affords an easy explanation of the universal appearance of the black cotton soil, except in the neighbourhood of those hills which are covered by granite alone.

We passed several little rivers on their way eastward to join the Manjira. An explanation of the cause of the total absence of trap on some of the hills must still be sought for.

Thursday, 11*th February* 1819.—Through the continuation of the plain to which Beechicondah is the pass. For some distance granitic sandy soil, when a river produced its usual accompaniment—the black cotton soil of the trap. We passed Mudnoor, at the back of which, to the N.E., the granite commences, surmounted by the trap. As we crossed the fields and ascended the hills of Bhuktahpoor, calcedony with green earth, heliotrope, amygdaloid wacké, with zeolite, stilbite, and carbonate of lime coloured green, were found in great abundance, and very fine specimens.

The western side of the hill on which we are encamped is composed of the crystalline transition greenstone, but in the valleys and towards

the eastern side it consists of wacké enclosing large specimens of foliated zeolite or stilbite with amygdaloidal pieces of green earth, which has given its colour to carbonate of lime also contained in it. The wacké is of a greenish grey colour, and is destitute of crystals of olivine or of basaltic hornblende.

Friday, 12*th February* 1819.—I visited a ravine about a mile due east of the hill, in which the trap was much water-worn. In one part it had very much the external appearance of the Rowley Rag Basalt described in Thomson's Annals, being semicolumnar. In another part it consisted of nodular concentric masses, of which the external coats were decomposed, leaving rings around a lump of more compact nature undecomposed, on others a number of concentric circles visible, of various sizes, according to the quantity of the mass decomposed.

Our servants have brought in a number of very handsome specimens of—

Wacké,	contg.	Foliated zeolite.
Ditto,	..	Green earth.
Ditto,	..	Green carbonate of lime.
Ditto,	..	Nodular mesotype, heliotrope.
Ditto,	with	Green earth and calcedony.
Ditto,	..	Jasper ditto ditto.

Saturday, 13*th February* 1819.—The surrounding hills and acclivities are of two descriptions. The lowest are of granite, are rugged, consisting of masses heaped one on the other, and of loggan stones. The lower are generally east and west, level at their tops, with now and then rounded summits terminating by rather an abrupt slope, and containing valleys having the appearance of the embrasures of a fortification; I recollect seeing the above hills mentioned by Colonel Mackenzie in his Journal. The basis of all these hills is granite, reddish and of a small grain.

Sunday, 14*th February* 1819.—List of minerals found on the hill and in the neighbourhood of Bhuktahpoor, during a residence of four days there:—

Basis of the hill, granite, of a reddish grey colour and small grain.

Granite.
Greenstone, earthy, contg.
Zeolite.
.. foliated.
.. radiated.
Heliotrope.
Carbonate of lime.
Green earth.
Calcedony.
Quartz.
Cacholong.
Striped agate.
Wacké, concentric.
.. globular.

Waeké, amorphous.	Carbonate of lime.
.. cellular.	Green earth.
Amygdaloid, contg.	Brown ditto.
Zeolite.	Calcedony.

Thursday, 18*th February* 1819.—We quitted Bhuktahpoor at four o'clock this morning. I had employed the three preceding days in visiting various parts of the neighbourhood. I found three streams of water descending from the hill in different directions supplied by infiltration: the temperature of one was 10° lower than that of the atmosphere, which was 88°. The waeké was not very general, and appeared only in beds of small extent, the general rock being an earthy greenstone with no crystals of any description. I found in all the sides of the streams the efflorescence of the carbonated alkali; and I am at a loss to determine whether it proceeds from the soda of the zeolite or the potash of the green earth. A dense precipitate was occasioned in water from a spring in the neighbourhood of the camp by alum in powder. I arrived at Daigloor a short time before sunrise; about a mile distant I crossed a river, the bed of which was composed of large blocks of red crystalline granite contained in a breccia composed of limestone cementing quartz and red felspar; the sand of the bed was similar to that of most other rivers that I have seen, taking their rise from the trap hills and flowing through granite country, consisting of the *débris* of those two rocks, as well as calcedonies and land shells of three sorts—buccinum, helix, and pupilla; the right bank of the river resembled exactly that at Ramaleddypett, being lofty and composed of the black cotton soil. I passed over other ranges of the trap of low height, until our descent into the plain through which the Mubnar passes, the right bank of which is also very steep.

At Adainoor the granite forms more than one-half the height of the hill, and is covered at the top by a very compact greenstone, with crystals of felspar, and a few cavities not filled with any substance. The course of these trap hills was very distinctly seen from this point due E. and W.

Saturday, 20*th February* 1819.*—I passed through the village of Mengoor, near which, on the banks of a small nulla, the thermometer sank to 47° just before sunrise: in its neighbourhood I also saw a bed of lithomarge lying on the alluvium, which rested, as usual, on the trap. The fields on my right and left were full of gram and corn crops; nevertheless, I observed that a large quantity of land had been thrown out of cultivation. The approach to the Godavery was over waving land consisting entirely of trap and alluvium; now and then beds of amygdaloid, with green earth and waeké, were seen, and within a mile

* Continued from page 212, *loc. cit.*

of the river small blocks of granite rising through the alluvium, so rounded that I found it impossible to bring away specimens. My visit to the rocks was first paid; I found them to consist of granite, forming the banks and bed of the river; the former were about forty feet high; of this height the granite occupied one-half, and the remainder consisted of black cotton soil; the river was shallow indeed. I crossed its deepest part, and found it vary from two to four feet in depth, its bed consisting of granitic sand mixed with a few calcedonies and agates, and, on the borders, magnetic iron sand; I did not see shells. In the crevices of the rocks I found some pieces of stilbite or radiated zeolite. The height to which the river rose two years ago was pointed out to me, it might be about thirty feet above its present level: it had washed away the corner of a wall surrounding a handsome pagoda built of black basalt: it must now, no doubt, have changed its bed materially, since tradition places the pagoda, many years ago, far from its banks. The temperature of the river at twelve o'clock was 74°, the same with the air. The basalt of which the pagoda is built is in some parts of the building finely polished. It contains olivine. The granite much resembles that found near Bachapilly at the Bear's Rock. It is porphyritic, containing large crystals of red felspar in a crystalline cement composed of quartz, compact felspar, and mica. This is the prevalent rock. A porphyritic greenstone lies near it, apparently in beds, in which the crystalline felspar is compact and of a green colour arising from green hornblende. I believe them to be the same with those of the Bear's Rock at Bachapilly. The distance from Thevalinga-pett hill is twelve miles, and the sole rock is the trap, sometimes basaltic, sometimes wacké on the elevations, and in the plains black cotton soil.

Monday, 22*nd February* 1819.—On quitting this place the thermometer stood at 47°, and the temperature of water at half-past five o'clock A. M. was 43°; a march of seven miles brought us to Monegal,—nothing but trap, of which I am heartily tired.

Tuesday, 23*rd February* 1819.—The formations in this part of India differ materially from those of Europe; no chalk, no intermediate rocks between the trap and granite. The whole field of view, probably, an extent of twenty miles. The ravines of the formation are much deeper than usual.

Sunday, 27*th February* 1819.—Large beds of wacké began now to appear, generally lower, or at the bottom of the more elevated trap hills. On arriving near, a temple with a basaltic column, similar to one I had seen on the banks of the Godavery, struck me, and I made an attempt to draw it.

Monday, 28*th February* 1819.—The river-bed differed very little from that of the Mulinar. I followed it until I came to the same or a similar

appearance, which had before struck me; large masses of red granite, imbedded in a coarse cement of limestone, containing crystals of felspar quartz, &c. I drew a sketch of the banks, which bore a great resemblance to those of the Mulinar and Manjira. We arrived at Buhtalipoor. In the evening I visited the formation of wacké, to ascertain a fact mentioned in Thomson's Annals confirmed. It was not calcedony in wacké.

Tuesday, 1*st March* 1819.—The configuration of the hills was very striking, with the same form I have before noticed, fewer peaks, and lying at right angles to each other in many instances. Once or twice I observed a complete quadrangle, all but one side, the opening being towards the plain.

Wednesday, 2*nd March* 1819.—A rugged road, from the frequent ascent and descent of the trap hills. On one of them I observed a vein of quartzose rock passing into flint running E. and W. I crossed the Seinde; the bed consisting entirely of black trap or basalt, very compact. At Dapky I lowered the temperature of Fahrenheit from 92° to 62° at sunset. I noticed a bed of lithomarge on my road.

Thursday, 3*rd March* 1819.—The hill on which the flag is fixed, about four miles and a half from Oudeghir, is covered with calcedony amorphous cellular with impressed crystals, and striped mammillary onyx, some imbedded in the cavities of the basalt; amongst them I found one piece of green amorphous calcedony. Five hundred yards from the tent I saw, on the side of a hill exposed by a slip, imperfect columns, of basalt resembling precisely the description in Thomson's Annals,—the Rowley Rag basalt. Oudeghir (the fort) stands on one of the flat hills so frequently mentioned, surrounded on every side by the semi-columnar basalt.

Friday, 4*th March* 1819.—I rode through the town of Oudeghir, which is entirely built of basalt. It is the largest native town I have seen, some of the streets wide and the houses neat. My sketch of the hills to the northward of the fort, when seated on a neighbouring hill on a level with it, is the best I could take; it ill represents the singular rise, one above the other, of the basalt, the hills representing to the eye an appearance of distinct strata, which reminds me of the Isle of France; beds of carbonate of lime are very frequent. I noticed on my way some columnar basalt in a large deposit to the left of the town.

Saturday, 5*th March* 1819.—In the evening I rode to the right of the town, and came to something very much resembling the iron clay, not very dissimilar to that of the Cape of Good Hope.

Sunday, 6*th March* 1819.—In the evening I rode to the basalt; I found one column, of eight sides, more than a metre in diameter; the interstices were filled with green earth, and sometimes with the globu-

lar wacké. In some of the columns I noticed depressions and elevations for the reception of a corresponding piece, as in the Giant's Causeway and Staffa. To the westward and southward all the hills have the same appearance, and I have no doubt that they are the same formation.

Monday, 7th March 1819.—I wandered over some hills to the left of Oudeghir, where I found trap tuff, wacké, and carbonate of lime (tuffaceous) in abundance, containing crystals of zeolite, apparently of fresh formation. At the bottom semi-columnar basalt, very black and of great specific gravity. On the right of the town there are very extensive ruins of houses and other buildings. The stream which struggles through the valley is fed by the infiltration from the hills. We passed, on our road to Doongong, over many pavements of basalt, some of them semi-columnar, with the interstices filled up by a secondary formation or ingestion of basalt; we saw also two remarkable elevations nearly north and south. In the neighbourhood of Doongong, vast quantities of wacké and basalt and trap tuff, alternating frequently and without order.

Wednesday, 9th March 1819.—The land is waving as usual, with a few abrupt acclivities from two to three hundred feet in height. The trap appears less subject to decomposition, having a very thin coat of soil, and in many parts it was found impossible to drive in the tent-pegs.

Thursday, 17th March 1819.—I found on the road the basaltic trap as usual, and in the neighbourhood of a ruined building some of the iron clay in lumps, apparently brought from some distance.

Saturday, 19th March 1819.—Reached Dammergidda at sunrise, and proceeded to the Manjira, which I crossed, and encamped at Chillelah, in sight of Beeder, distant about five coss, seated on a hill. The left bank is of the black alluvium, about fifteen or twenty feet high, sometimes much less; the right bank rises to upwards of sixty feet in height, forming a hill of considerable size, on which Chillelah is seated; the bank is composed of large masses of an earthy and crystalline brown limestone, very much water-worn, and containing large cavities, which appear to have been formerly filled by pieces of wacké, in some places containing large masses of flint, and in others forming a compound rock, being a cement to a rocky compound of wacké basalt, clay, and flint. Near the upper part it has the appearance of regular stratification, and on its top wacké, easily decomposable, is spread over it. I have yet to observe it more closely. The carbonate of lime contains a small portion of alluvium.

Sunday, 20th March 1819.—I bathed twice, and collected on the bank of the river a large quantity of the iron sand, which I suppose to contain iron ore, very little of it being taken up by the magnet. I also found

very fine clay. I took a ride in the evening and a sketch of the hills near Beeder.

Monday, 21*st March* 1819.—I took a more accurate survey of the banks of the Manjira in the neighbourhood of Chillerjee. The confusion or mixture of the two rocks is much greater than I at first imagined. I noticed, close to the present level of the river, a rock of compact basalt, which, at the distance of three or four feet, becomes wacké, passing into the admixture of carbonate of lime and lumps of wacké, and that again into the porous limestone containing clay and green earth, presenting externally large cavities out of which those substances have been washed; above the limestone is a brownish wacké on which the town is built; the height of the whole is about forty or fifty feet: the banks below and above were composed of the black alluvium, but I was told the limestone was found in considerable quantity both above and below. The height of the river was rather distinctly marked, during the rainy season, by the impression it had made on the foundations of a mosque built on its bank.

Tuesday, 22*nd March* 1819.—A short distance from the hill on which Beeder stands the soil gradually changes from black to a reddish tinge, from the decomposition of the iron clay of the range, of which and on which Beeder is built. This is the greatest elevation of the iron clay that I have seen in India, the barometer indicating 2,000 feet above the level of the sea. In some places, particularly in those excavations near the fort, it resembles very much the iron clay of Nellore, containing in its vesicles lithomarge, and the wells are generally very deep, one measured forty cubits; the temperature of the water was 78°. The iron clay contains lithomarge as usual, and it approaches a plumb-blue colour. I ascended the tower on which the flag was, and could not avoid noticing the flatness of the isolated mountains which had before struck me in so many instances.

Wednesday, 23*rd March* 1819.—I noticed greenstone, granite, and basalt in different parts of the building, which was chiefly composed of the iron clay and bricks.

Friday, 25*th March* 1819.—I rode this morning down the hill into the plain to the northward; the iron clay presented in no instance an appearance of stratification, but I noticed in several instances a gradual transition from it into wacké and thence into basalt, of which there are numerous little elevations in the neighbourhood. I noticed also lithomarge in considerable quantities, both in beds and in the rock itself. I re-ascended to the southward, finding the iron clay vary in form, and in some instances degenerating into an ochery soft clay. It must be observed that the iron clay itself is very soft when first quarried, and becomes indurated on exposure to the air. To the south-east a curious

sight presented itself in the form and disposition of the hills, of which I made a sketch taken in a different direction; the flattened summits were here most distinctly seen with the bevelments of the usual angle; around these were several small conical summits entirely isolated; some, on the contrary, were of a flattened rounded form, intermixed, consisting evidently of basalt.

Saturday, 26th March 1819.—I recommenced my observations on the hill of Beeder, and this morning rode to the north-westward. I every-where saw the basalt at the foot of the hill passing into wacké and iron clay; in one place the transition did not occupy more than three feet, and was very distinct. This easily explains the depth of the wells in the fort and the tower; the very porous iron clay being unable to hold the water, it drips through, until it meets with the basalt. It is proper here to observe that in most instances the vesicles or pores of the rock had the appearance of long hollow tubes, always vertical. The basalt was not confined to the valley, but was found in a considerable number of elevations of all forms, around. I observed on the western side several springs just above the level of the basalt. The singular improvidence and want of foresight in the builders of the fort was very evident in several places: finding the rock so very soft and easily worked, they excavated or rather cut it down even with the wall; it has subsequently mouldered, and the wall has been precipitated with it. The high land, projecting into the valley or plain through which the Manjira runs, like a number of buttresses, resembling very much that at Sudghir, is seen to the westward; to the verge of the horizon to the eastward the hills have a more abrupt and irregular character. The magnetic needle did not appear to be affected by the iron clay rocks. I visited a manufactory of Beeder buttons: the basis pewter; the design, whether of flowers or other pattern, is chiselled out of the black ground by an instrument fitted for the purpose, a paper is pressed strongly over it, which takes the sharp edges of the design, and this paper is placed on a thin sheet of *silver** for the purpose of cutting it into the requisite forms; these are then inlaid, and the edges of the pewter pressed down, so as to enclose the silver completely.

Sunday, 27th March 1819.—Temperature of two springs on the N.W. side of Beeder 76°, of neighbouring water 73°. I again examined the passage of the basalt into the iron clay. In some places the passage from the almost columnar basalt into nodular, and then into the iron clay, is very distinct; on the other hand, in other places the basalt appears to pass under it, and in some instances forms a causeway in the path, at the side of which rises the iron clay.

* Copper and silver nearly equal parts.

Monday, 28*th March* 1819.—I ascended the minaret and had a fine view of the country: the whole to the southward, eastward, and westward had the appearance of a vast elevated plain; to the north it terminates in the projecting buttresses of iron clay into the valley through which the Mayna runs, and which is ten miles in breadth.

Tuesday, 29*th March* 1819.—From Beeder we began immediately to descend to that ground which appeared from the minaret to be an extensive plain, consisting of numerous elevations and depressions, or a collection of several plains intersected by deep ravines. The whole consisted of iron clay, but on our road to Shelapilly four zones of the black cotton soil intersected our path, running due north and south; the difference was strongly marked. The iron clay soil was almost incapable of cultivation, and the other presenting its usual appearance of fertility. We are at present encamped on one of these zones, having a direction nearly north and south: at the foot of a conical elevation of forty feet, composed entirely of earth from the top, the iron clay is seen on each side at the distance of a quarter of a furlong. Query, is this hill the focus whence this muddy eruption has issued? One more is visible in the plain about two miles distant. The earth at the depth of two or three feet is sufficiently moist to allow it to be made into a ball with the hands. Temperature 5° below the atmosphere.

Wednesday, 30*th March* 1819.—I visited the small hill I have before mentioned, and found reason to suppose it artificial. The black soil was in some places intermixed with the trap clay, and in others was in indistinct zones, all with N. or N. by W. direction.

Thursday, 31*st March* 1819.—We descended from the iron clay during the night, and in the morning found ourselves on the black soil in a level plain. I found considerable quantities of carbonate of lime intermixed with the wacké, which is here found in the same nodular masses with a hard kernel which I have before noticed at Bhuktahpoor. The soil contained a large quantity of carbonate of lime, effervescing considerably with acids.

Friday, 1*st April* 1819.—I crossed three nullas on my road to Sedashewpett, during a journey in the dark, all running eastward, along a ridge of gently undulating and sightly elevated land, as seen to the eastward as day broke, apparently a continuation of the Tadmanoor range, and taking the same direction. At daybreak I fell in with large masses of granite lying in the black soil, and in a ravine saw plainly that it formed the substratum covered with the cotton soil, although not in all parts, the soil being granite in the highest part. To the westward are seen the flat tops of the trap hills and the peculiar abrupt termination of the iron clay of Beeder. The soil in which we are is nearly all granitic. The intolerable heat of the day has prevented my

excursions for some time past. The valley in which we are is hotter than at Hyderabad.

Monday, 12*th April* 1819.—I traced the trap veins into the granite and farther east than I could follow it; it is precisely similar to that of Golcondah, Suldapooram, &c. I nowhere observed it in contact and passing into the granite. It extends as far as the eye can reach in an easterly direction, sometimes forming considerable elevations, and at others, sinking beneath the surface, is scarcely visible.

Thursday, 22*nd April* 1819.—Twenty-six grains of the green carbonate of lime were dissolved in nitric acid; result to be hereafter mentioned. About three miles to the N. W. of the cantonment I observed a long deposit of quartz rock. The whole of the above green lime was dissolved except 3½ grains of green earth, which remained behind on the filter.

Thursday, 29*th April* 1819.—Specific gravity of calcedonic agate from the Godavery, 260.

6*th May*.—Specific gravity of Tadmanoor basalt, 2·816.

11*th May*.—Specific gravity of flint from Medcondah, 2·63.

13*th May*.—Epidote from Multapoor.

Sp. gr. ....3·312.

13*th May*.—Green hornblende from the Carnatic.

Sp. gr. ....3·243.

30*th May* 1819.—Here commences my expedition with Everest during the rainy season.

4*th June* 1819.—To the left of the road before reaching Hyderabad I observed a deposition or bed of quartz rock which I ascended, but was not able to discern its termination on either side, its direction was due north and south. The granite in the bed of the river Mussy was reddish, inclining to grey. The evening closed too soon on me to allow of any observations before reaching the camp.

5*th June* 1819.—I arose with the sun, and ascended the hill, which rises about 100 feet above our encampment. I observed a vein of the greenstone precisely resembling that of Golcondah and Secunderabad, its direction E. and W. as usual. The granite is of a greyish colour, containing large crystallized masses of felspar of a similar colour to that observed at Ardinghy.

I no longer observe loggan stones; the granite is more compact and less liable to decomposition. About a mile from the station, in a westerly direction, I observed a long vein or deposition of quartz rock running north and south, probably a continuation of that observed yesterday; also on the ground numerous small concretions of carbonate of lime.

6*th June* 1819.—I quitted the camp early for Chitterghat. The

granite was generally of the reddish grey colour, with loggan stones, but fewer than I have observed in other parts.

7th June 1819.—We arrived at Ballapooram, distant eight miles from our last station: the vein of greenstone was observed to our right running nearly east and west. At one period it crossed our path and we lost sight of it; soon after, at this place, we had heavy rain during four hours.

8th June 1819.—We passed through Hyattnuggur, and saw a trap vein to the right of our road, which accompanied us for a considerable distance; it re-appeared at Seringhur, on the side of a granite hill.

9th June 1819.—The granite between Seringhur and Mulkapoor we found to be at times very red and close-grained. The trap vein was frequently in our path, but very much decomposed, and by an inexperienced eye would not have been distinguished from the granite. At Mulkapoor it assumed its usual character.

This place is situated at the northern extremity of a valley about five miles in length by one and a half in breadth; the hills rise on each side to the height of nearly 600 feet; they are of granite, which for the most part is of a grey colour, containing large crystals of bluish grey felspar. The large trap vein crosses this valley, which is nearly north and south, and disappears on the eastern side amongst the rocks. It is here of large dimensions, and appears to contain large pieces of epidote, as I found large pieces of that mineral at its foot.

10th June 1819.—I was one hour going to the top of the hill, where a flag was fixed. I found the granite much whiter than that below, which contains hornblende and compact felspar.

The view was very much bounded by the mist. I observed a few loggan stones, and the same irregular appearance of the rocks as in the neighbourhood of Hyderabad. The barometer stood at ten o'clock at 29° 4′, thermometer 84°; below the hill at 70° 8′, thermometer 80°. In the evening I visited the trap vein. I found a considerable quantity of epidote, also a few pieces of amethyst quartz; the vein runs due E. and W. I was afraid to trace it on account of the tigers.

17th June 1819.—I saw several veins of the trap running in a different direction from that usual to them; they appeared, however, to be continuations of that large one which I observed at Mulkapoor.

18th June 1819.—On the road I observed several trap veins and deposits on the mountains, but was not able to inspect them more closely on account of the jungle. At this place two veins were observed, the one due E. and W., coming from a considerable distance, and a small one, on which was a pagoda, nearly at right angles to it, of small extent.

19th June 1819.—I reached Secunderabad this morning.

Notes, chiefly Geological, across the Peninsula from Masulipatam to Goa, comprising Remarks on the Origin of the Regur and Laterite; occurrence of Manganese Veins in the latter; and on certain traces of Aqueous Denudation on the Surface of Southern India.* By Captain Newbold, F.R.S., Assistant Commissioner, Kurnool.†

Masulipatam stands on the sea coast in nearly 16° N. lat., and about twenty-eight miles N. from the principal northerly embouchure of the Kistnah.

The adjacent country is the flattish maritime plain which, according to Benza, extends between the mouths of the Godavery and the Kistnah.

The alluvial sands that cover the surface rest on a bluish black tertiary or post-pliocene clay, resembling regur, imbedding terrestrial marine shells of existing species, and apparently identical with the black clay beds underlying the cities of Madras and Pondicherry, and other places on the Coromandel Coast. In many places the overlying sand is aggregated into a loose sandstone of a nodular form, and often perforated with sinuous and straight cavities, the work of *pholades*. The structure of this sandstone, which contains fragments of recent shells, is here concretionary. The cementing matter is clay and carbonate of lime, with a little oxide of iron. The sand continues to cover the plain to the distance of fifteen or sixteen miles inland, partially underlaid by these beds of black clay, to within some miles of Bezwarah, when the gneiss is first seen to outcrop from these recent strata.

The plain of Masulipatam, it is quite clear, once formed the bottom of a lagoon, or marine lake, and was elevated and dried up probably in the post-pliocene period. The channel of the Kistnah, which it is likely supplied much of the fresh water, appears to have suffered a southerly deflection from the elevatory forces and consequent alteration of surface.

At Bezwarah the gneiss rises into a ridge 600 feet high, running N.E. and S.W., its dip confused and contorted. Through a gorge in this ridge, at right angles with its direction, runs the Kistnah. No evidence could be discovered of the Kistnah's having cut the channel through the

* *Regur,* the black, tenacious, but usually fertile soils of Central and Southern India are known by this name.—Eds.

† Reprinted from the Journal of the Asiatic Society of Bengal, vol. xiii. p. 984.

ridge: it appears to have been originally formed, like the transverse river courses, through the chalk escarpments of the Weald, by the elevatory forces that raised the strata to their present position. The features of the original fissure have doubtless been modified by the abrading power of the river, which, when swelled by the freshes, entirely fills the gap, about a mile in width, its sides rising rather precipitously from the river's banks.

Beyond this ridge, which is of no great length, the surface of the country appears flat as before, and the rise from the coasts scarcely perceptible. With regard to the theory of the tract between Bezwarah and Condapilly having once formed the bed of an extensive lake, my friend Mr. Malcolmson has justly observed, that "a careful survey of the hills from the summit shows that they are short insulated ranges, such as are found over the Circars and other tracts rising from a level country; and that, had a lake existed in the plain above, every slight rise of the river would have carried its waters round their shoulders to the north and south."

The gneiss composing the ridge of Bezwarah is garnitiferous. Cleavelandite often replaces the common felspar, and renders the gneiss liable to decay. It contains large veins of quartz, and is intersected by greenstone dikes, the presence of which may serve to account for the distortion observable in its strata.

A little to the N.E. of Bezwarah are the diamond mines of Mallavelly, where the gneiss is in some places covered by a conglomerate sandstone, resembling the diamond conglomerate of Banganpilly and Kurnool, and of which it appears here as an outlying patch. The diamonds are, however, dug for in a bed of gravel composed chiefly of rolled pebbles of quartz, sandstone, chert, ferruginous jasper, conglomerate sandstone, and kunkur, lying under a stratum of dark mould about a foot thick. Dr. Benza traced the conglomerate sandstone hence by Ellore and Rajahmundry to Samulcotah.

From Bezwarah by Condapilly to the vicinity of the Warapilly ghàt, the hypogene schists, chiefly gneiss and granite, occur. East of Warapilly these rocks are covered by the northern termination of the Cuddapah limestone beds. The diamond sandstone associated with this limestone stretches still further north, as already mentioned, by the diamond pit of Mallavelly to Samulcotah.

A little north of Warapilly, granite and the hypogene rocks continue to Hyderabad, and forty-eight miles to the N.W. of that city to the village of Moonopilly, on the Beeder, where they are covered by the great overlying trap formation.

Most of the rocks about Hyderabad are of granite; that of Moeb Ally is of the laminar variety, often approximating to gneiss. The rock on

which stands the celebrated fortress of Golcondah rises in the centre of the valley of the Moossi, about six or seven miles westerly from Hyderabad, and is composed of a granite with reddish felspar, translucent quartz, with dull dark-green mica, and a few crystals of hornblende. Of this granite, which resembles that of Syene, the domes and outer walls of the Mausolea of the old Golcondah kings are built. Through this royal cemetery runs a dike of a dark crystalline greenstone, nearly E. and W., which is probably identical, from its direction, with a dike observed six miles west of this, between the British residency and the great tank of Hussain Saugur. The rocks of the dike bear evident marks of the chisel, and, no doubt, furnished material for the sepulchres of the Golcondah kings, which are constructed of this or an exactly similar greenstone exquisitely polished.

From Golcondah the road towards Beeder lies, for the first few miles, over the low granitic ridges which form the northern side of the valley of the Moossi, to Lingumpilly, near which the ridge gently sinks into an undulating plain. Between this village and that of Puttuncherroo, which is situate about eighteen miles W. by N. from Hyderabad, the face of the country has a gentle N.W. declination towards the bed of the Manjira. Granitic rocks constitute its basis as far as Cummumpilly, about fifty miles W.N.W. from Hyderabad. The granite is both of the small-grained, red felspathic variety, and large-grained. Both varieties are met with at Kundi and Moonopilly, forty-eight miles from Hyderabad. The small-grained is seen to penetrate the other in sinuous veins. There is also a third variety, fine-grained, containing much quartz and imbedded nests of a dark steel-coloured mica. Veins of reddish felspar, with actinolite and a little quartz, also are seen. Both granite and gneiss, and the veins by which they are intersected, are penetrated by dikes of basaltic greenstone; the largest dikes observed were east of Puttuncherroo, a little west of Lingumpilly and Mootinghi; also at Sedashipett and Yernanpilly. The Mootinghi dike runs nearly N. and S., the rest preserve an easterly and westerly direction. The felspar of the granite and gneiss, near the line of contact, is deprived of its lustre and translucency, and becomes opaque and white like porcelain; the mica either almost disappears, or shrinks and becomes hard, compact, and of a ferruginous aspect, while the rock *en masse* acquires a tendency to split into rhomboids. Near the line of contact with the overlying trap, a reddish felspathic zone is observed similar to that described as occurring on the trap and granite boundaries at Gurdinny in the Southern Mahratta Country, south of Bejapore, which passes into pegmatite *soil.* The soil from Hyderabad and Golcondah to Puttuncherroo is generally the light reddish sandy detritus washed down from the granite heights in the vicinity, occasionally mingled with nodules of a ferruginous clay

resembling the *débris* of laterite. A little to the N. and W. of Puttuncherroo the granitic soil thins out and disappears, leaving exposed the sheet of regur that underlies it, and which occurs first at intervals, but afterwards as an almost continuous sheet from Moonopilly to Beeder.

Between Puttuncherroo and Moonopilly the strips of granite alluvium with which it is alternated appear to have resulted from the decay of *salbandes* and bosses of granite, which formerly outcropped from the bed of the regur, but have since crumbled down by a process of weathering, which I have described elsewhere; and, being washed by the rains, have covered the surrounding soil with a sandy detritus, thus (see Plate I. Diagram, fig. 3) :—

A. Undecomposed granite.

BBB. Decomposed granite, forming an alluvial surface soil.

CC. Regur.

Near Sedashipett a stratum of kunkur intervenes between the regur and the granite. The surface of the regur, where it overlies the trap from Moonopilly to Beeder, is often intermixed with the detritus of the outcropping trap and laterite rocks associated. The soil resulting from the disintegration of the former is easily distinguishable from the regur by its much lighter and reddish tinge, arising from the peroxidation of the protoxide of iron it contains. The detritus of the darkest portions of the trap, even before peroxidation takes place, have a greyish or greenish-brown hue, totally dissimilar to the regur.

Boundary of the great overlying trap formation of the Deccan.—A little to the W. of Moonopilly, rounded and angular fragments of the trap of the overlying formation are seen lying on and partially imbedded in the regur, with scattered, rugged, scabrous blocks of a compact cream and buff-coloured limestone passing into chert. The latter contained a cast of a small fresh-water shell resembling a *Physa.*

Ascending the gentle slope beyond the village of Cummumpilly the overlying trap was first seen *in situ* in a section afforded by the steep bank of a nulla. The trap is petrographically identical with that of Bejapore. The structure is at once sheeted like that of modern lavas, imperfectly columnar and globular. The globular trap disintegrates by a process of concentric exfoliation. The concentric coats weather into a brown speckled, friable wacké, which, falling off and washed away by the rain, leaves the hard spheroidal nuclei of basalt scattered on the surface,—frequently in such numbers as to present the appearance of having been showered down by some volcano. These spheroids vary in size from a pigeon's egg to a 16-inch shell.

Recent conglomerate.—A few miles to the south of Sedashipett, a low flat-topped range of hills is seen, which, from the calcedonies, jasper, and fragments of trap brought down by the nulla, are probably of trap.

These transported pebbles have been formed into a solid bed cemented together by lime, and form cliffs from three to ten feet in thickness on the nulla bank. Small rounded fragments of laterite are also included in this recent conglomerate, which is also seen in the beds of other rivulets between Moonopilly and Beeder. These conglomerates rarely extend more than twenty or thirty yards from the present channels of the streams, and generally not above several feet. The lime contained in the water of the stream and its tributary springs has evidently assisted in the consolidation.

About four or five miles S.W. from Moonopilly the low range of hills there seen was found to be of trap; the highest peak capped by a lateritic rock resembling that of Hor Muth south of Bejapore, described pp. 6 and 7, No. 2 Geological Notes. This laterite, near its junction with the trap, passes into a bed of crimson-spotted, lithomargic earth, resembling that of the Neilgherries, and is slightly impregnated with calcareous matter. The trap occupies the lowest situations, and constitutes the basis of the plain to Beeder, where it is overlain by an extensive bed of laterite 200 feet thick.

Laterite Bed of Beeder.—The laterite bed of Beeder commences about sixteen miles E.S.E. from that city: it is first seen resting on the trap in a bed about 100 feet thick, forming a hill, shaped like a truncated cone, about two miles S.W. from the village of Sungum. Thence it continues capping the trap with little interruption, and forming the surface rock of the level and extensive tract of table-land on which the city of Beeder stands. The laterite bed terminates to the west about twelve miles W.N.W. from Beeder, descending to the plain by a short but steep declivity, and at its basis the trap is again seen. It is about twenty-eight miles in extent from E.S.E. to W.N.W., and about twenty-two miles from W.S.W. to E.N.E. Its average thickness is about 100 feet, and maximum 200 feet; it rises from the trap of the plain in abrupt and sometimes precipitous acclivities. The cliffs supporting this table-land of laterite on the northern and eastern sides are from 100 to 200 feet high, but much lower and less abrupt on the west side, where the general level of the country appears to rise. The general direction of the cliff line, marking the termination of the bed near Beeder, is E. by S., but the outline is irregular, the cliffs forming salient and re-entering angles.

The plain on the summit is almost one monotonous level, and less broken by nullas than is generally the case on table-lands. This appears in part owing to the rain water being mostly drained off through the porous structure of the rock before it has time to collect.

The height of this table-land above the sea, as barometrically taken by Voysey, is 2,359 feet, about 200 feet lower than the indications afforded

me by means of the boiling-point of water. Sheets of bare laterite impart a barren appearance to portions of its surface. The soil resulting from the disintegration of the laterite is brown or reddish, gravelly or pulverulent, according to the varying petrographical structure of the parts of the rock of which it is composed. The soil formed from the dark and siliceous varieties is usually sterile, but that from the softer and more argillaceous varieties is carefully cultivated, producing abundant *mungári*, or early crops. The yellow *juare* and *bajra* grown on it are said by natives to be sweeter than those produced by any other soils. It seems probable that among other causes of the sterility for which lateritic soils have been abused may be ranked that of the porous character of the laterite when it forms the substratum which carries off the water, particularly from the loose siliceous varieties of the soil, before it has had time to fertilize the surface. In the more clayey kinds of the soil the water is longer retained. In the immediate vicinity of Beeder the soil does not lie thick, and the trees have a stunted appearance, particularly the mango trees that shade most of the Mausolea and tombs in the precincts. Wherever there is a sufficient depth of soil and capability of retention of moisture its chemical nature is certainly not against arboreous vegetation, as the picturesque banyan tree in front of the cavern spring in the Farabagh can testify. On the summit of the table-land a few narrow belts of the regur occur outcropping from the alluvium. Voysey counted four well-defined zones of the cotton soil on this elevated insulation, between Beeder and Shelapilly, running N. and S., and lying between ridges of laterite, termed by him "iron clay." The fact of its being thus found on the tops of hills, and covering the bottoms of valleys and plains, at a distance from any river's course and out of the reach of present inundations, militates strongly against the theory of the regur being a fluviatile deposit, as thought by some.

The principal wild shrubs growing in the lateritic soil on the surface are the *Pulas*, the *Kutlungi*, or *Chunqu Cheltu;* the *Cassia auriculata*, the *Anana squamosa*, *Asclepias gigantea*, the *Bair (Zizyphus Jujuba)*, the Acacia, the *Cara thorn*, and the small-leafed *Burratiri*.

Petrographical character of the Beeder Laterite.

The laterite of Beeder, generally speaking, is a purplish or brick-red, porous rock, passing into liver-brown, perforated by numerous sinuous and tortuous tubular cavities, either empty, filled, or partially filled, with a grayish white clay, passing into an ochreous, reddish and yellowish brown dust; or with a lilac-tinted lithomargic earth. The sides of the cavities are usually ferruginous, and often of a deep brown or chocolate colour: though generally not more than a line or two in thickness, their

laminar structure may frequently be distinguished by the naked eye. Before the blow-pipe it melts into a black clay attracted by the magnet, but is rarely so ferruginous as to entitle it to the character of an ore of iron, though some of the nodules are picked out and smelted by the natives. The interior of the cavities has usually a smooth polished superficies, but sometimes mammillary, and stalactiform on a minute scale. The hardest varieties of the rock are the darkest coloured and most ferruginous. The surface masses of the softer kinds present a variegated appearance. The clay and lithomarge exhibit lively coloured patches of yellow, lilac, and white, intersected by a network of red, purple, or brown. The softness of this rock is such that it may be cut with a spade,—hardening by exposure to the sun and air, like the laterite of Malabar. The surface of the harder or more ferruginous varieties is usually barren, flat like a pavement, and often presents a glazed or semi-vitrified appearance. The *débris* of this rock, washed from its surface by the rains, is often seen accumulating in low situations, and reconsolidating into a nodular conglomerate; when the fragments of the laterite have been much rolled they assimilate externally to pisiform iron ore, but have neither its specific gravity, internal concentric structure, nor distinguishing lustre. The felspathic cement agglutinating these nodules is often of a deep brown colour, passing into various lighter shades according to the quantity of iron it contains, and is evidently composed of the more powdery parts of the parent rock. This alluvial laterite is seen in all lateritic areas in the south of India, and is as easily to be distinguished by its nodular and pisiform character, its position and the thinness of its beds, from the true laterite, as the reconsolidated *débris* of quartz, mica, and felspar is from the true granite rocks; at the basis of which it is often seen in India to accumulate in beds of some thickness and tenacity. In tracts where kunkur and limestone prevail, as near Bejapore and Bangwari, the lime often enters into the cement of this lateritic alluvial conglomerate.

Sections of the Laterite presented by the cliffs and wells of Beeder.

In the sections afforded by the faces of the cliffs and deep wells of Beeder the laterite sometimes presents a homogeneous cellular structure from summit to base. Generally speaking, however, it becomes softer and more sectile as it descends; and the cavities in the lower portions are better filled than those higher up. This may be attributed in some measure to the action of the rain, which, falling on the surface, percolates through the cavities of the upper portions of the rock, carrying downwards much of the ochreous and lithomargic earths they contain, until at length the cavities of the lower parts of the rock become so full that they form an impervious bed, where the water collects in hollows

and cavities. Here it accumulates until it either trickles through the passes of the side of the cliff, or finds its way out by some of the nearly horizontal joints that intersect the rock. Such are the sources of the shallower wells and springs observed in the substance of laterite rocks. The deeper wells and springs are usually found at its basis, where it rests upon the impervious trap. Near the line of junction the trap is almost invariably observed to be in a state of disintegration, either as friable wacké, or as a brownish or greenish grey clay. The laterite is no longer hard or porous; its cavities are broken up or filled with lithomarge and ochreous earth, and, in short, it presents a dense bed of clay variegated with shades of purple, red, yellow, and white. This clayey state of disintegration of both rocks is ascribable chiefly to the collection here of the percolated water from above. The line of demarcation between the two rocks is not easy to distinguish, as the clays are intermixed by the water; that of the trap is easily to be distinguished, at a little distance from the contact, by its greenish hue and soapy feel; that of the laterite is often meagre to the touch, and either white or tinged of various shades by iron. The disintegration of the trap rock rarely extends more than four or five feet below the junction.

The tabular cavities in the laterite have not unfrequently a horizontal direction, and, where numerous, impart a somewhat laminar structure to the rock. They are observed to be most numerous where the water, being obstructed from passing lower down, is compelled to find its way to the sides of the cliffs; empty sinuous tubes, having a general vertical direction, are also observed varying from a few lines to one or two inches in diameter passing through the rock; one was traced thirty feet until it disappeared in a projecting portion of the cliff. These cavities are sometimes lined with drusy crystals of quartz. The surface of the interior is generally ferruginous and shining, and sometimes mammillary and stalactiform.

Veins of manganese in the laterite.—I am not aware that any writer on laterite has noticed the occurrence of veins of manganese associated with oxide of iron in this singular rock, a mineral which has probably afforded the beautiful lilac colour seen in its lithomargic earth. At the western base of the cliffs, about sixteen miles W. by N. from Beeder, and a mile and a half from the village of Hulfergah, on the left of the road leading down from the table-land into the plain, the laterite is seen penetrated by a great number of veins, which, at first sight, from their dark aspect and singular direction, might be taken for those of basalt. They are composed of black, often earthy manganese, combined with iron. The veins are extremely tortuous and crossing each other in every direction, and give a reticulated appearance to the rock. On the sides of these veins the laterite is so hard as to stand out

in relief from the weathered portions of the roek. The veins are usually thieker near the bottom of the eliff, fining off as they aseend, until they are gradually lost in the substanee of the laterite; others are horizontal. As they diminish from an ineh to a line in thiekness, they gradually lose the deep bluish-blaek eolour, beeoming mixed with the matter of the matrix, and pass into a brown, yellowish-brown, and, lastly, a purplish thread, whieh is lost in the substanee of the roek.

The bluish-blaek substanee of the veins is compaet and hard, in some parts; seetile and earthy in others, easily frangible. Before the blow-pipe, *per se*, it is eonverted into a blaek slag affeeted by the magnet; with borax it fuses into a bead of amethyst-eoloured glass.

The indurated sides of the veins are of a mottled reddish-grey eolour, resembling indurated lithomarge: portions of the greyish-white elay in their vieinity aequire an almost vitreous hardness and a eellular fritty aspeet; a dull greenish enamel lines most of the cavities in the laterite. The lithomarge is slightly indurated. The gritty parts of the roek exhibit traees of ealeareous infiltration. The greyish-white elay fuses into a greenish enamel, similar to that lining the eavities. The pure lithomarge undergoes little alteration before the blow-pipe,—does not fuse, but beeomes indurated, darker, and more mottled. The impure varieties exhibit in the redueing flame minute greenish globules.

The lithomarge, and the greyish white and eoloured elays, all emit air-bubbles when plaeed in water; they also slightly deerepitate, but do not fall to pieees; with water they form a plastie elay. The purer varieties of lithomarge are little adhesive, feel meagre; the streak and fraeture is earthy: that of the white elays shining, they feel slightly greasy to the toueh.

It must not remain unnotieed that near to the base of the laterite cliff, in whieh the manganese veins just deseribed oeeur, runs a dike of eompaet and exeeedingly tough basalt, oeeupying the spaee of a few yards in breadth between the laterite and the trap of the plain. There I was unable to diseover any veins of manganese either in the latter or the basalt.

The basalt of this dike is seen, in the bank of an adjoining nulla, to assume both the globular and eolumnar strueture.

Valley of Denudation.—At the N.E. extremity of the eliffs of Beeder an instruetive example of a valley of denudation and exeavation, about a mile in breadth, is afforded, of whieh the following is a seetion. It shows at the same time the immediate superposition of the laterite on the overlying trap of the Deeean. (Plate I. Diagram, fig. 4.)

AA are eliffs of laterite from 120 feet to 90 feet high, onee evidently a eontinuous bed over BBB, sheeted trap and amygdaloid, and oeeupying CC. The spaee DD, hard, ferruginous masses of laterite. Though

evidently much water-worn and disrupted, they have successfully maintained their position against the transporting effects of the stream, which not only stripped off the laterite and denuded the subjacent trap, but excavated the latter to the depth of many feet, having the hard mass *Ba* in the centre, and the valley of denudation and excavation DD.

This valley runs E. by S., and over the plain at its eastern extremity are scattered the harder nodular fragments of the stripped laterite mingled with regur, and the recent lateritic alluvium of the adjacent cliffs.

Economical uses of the laterite of Beeder.—The laterite, particularly its closer varieties, has been largely used in building the city walls; in the revetements of its ditches, wells, &c. and in the construction of the more common cemeteries. The principal edifices, walls, and bastions of the fortress are of the trap. The laterite quarries of Beeder resemble those on the coast of Malabar and Canara, but are deeper, in consequence of the sectile beds, which are usually preferred, lying deeper below the surface than in Malabar, where the far greater moisture of the atmosphere may have some effect in preserving the moisture and sectility of the upper parts of the rock. Both rocks harden on exposure to the air. There is little appearance of stratification in the cliffs; and, on the other hand, no tendency to a prismatic, columnar, or globular structure. The rock has much the appearance of those enormously thick-bedded sandstones, where, in cliffs even of 200 feet high, there is no alternation of other beds; and the rock appears one unstratiform trap, often cleft, by vertical fissures, into columns and pinnacles.

I have dwelt longer upon the subject of the Beeder laterite than at first sight might appear to merit, but I may plead in extenuation that it is the first bed seen, beyond the granitic and hypogene area, resting on the overlying trap, a rock (the nature of the rock on which it rested had been differently stated by Malcolmson and Voysey, by the former as granite, but the question, however, by this visit has been set at rest for ever) which probably belongs to the tertiary period. Calder, to whom we are indebted for the only general view of Indian geology hitherto published, and whose ideas have been quoted by some eminent European geologists, terms laterite "a contemporaneous rock associating with trap, and commencing only where the overlying trap ends, a little to the N. of Bankote, or Fort Victoria, and thence covering the primitive rocks of the ghâts and W. coast to Cape Comorin." Now the laterite of Beeder and many other localities, some of which will be described in the course of this paper, lies beyond the area of the rocks termed primitive by Mr. Calder, and rests *upon* the overlying trap; it has never been observed underlying or alternating with it; therefore, the only proofs available, viz. that of superposition and non-alteration,

tend to prove its more recent and non-contemporaneous origin,—a point of great importance. The existence in it of veins of manganese, and of large beds of the same mineral I afterwards discovered in the laterite area capping the granitic and hypogene rocks of the Kupputgode range in the South Mahratta Country, are remarkable facts worthy of note, for, until we find beds and veins of this mineral in the granitic and trappean rocks underlying the laterite, we must be slow to admit the theory advocated by several geologists of the latter being nothing more than the result of the recent disintegration of the former rocks *in situ.* The beds of lignite discovered by General Cullen and myself in the laterite of Malabar and Travancore, and the deposits of petrified wood in the red hills of Pondicherry, in a rock which, though differing in structure, I consider as identical in age with the laterite, and other facts, too long for enumeration here, point rather to its detrital origin like sandstones. I do not ever recollect having seen, in the laterite resting on the overlying trap, any fragments of the calcedonies or zeolites that often so greatly abound in the rock immediately below it, a fact which, while decisive against the decomposition *in situ* theory, would lead us to the inference that the laterite owed its origin to the detritus of other rocks than the overlying trap.

Laterite, by many geologists in Europe, is supposed only to fringe our coasts and exist as a thin cap on the ghàt summits ; every day, however, is adding to our knowledge of its extent in the interior of the peninsula ; and it is evident not only that it must have covered it formerly to a much greater extent than at present, but that it has since been much broken up by the subsequent denudation, of which, on the small scale, Beeder affords a specimen (*vide* Section). The effects of this denudation, however, are visible on the grand scale in the interior of Southern India, where the tops of mountains of granite, hypogene rocks, and sandstone, many miles asunder, are seen capped with laterite in almost horizontal beds, and little or no laterite in the intervening plains and valleys, as in MacCulloch's description of the great denudation of the red sandstone on the N.W. coast of Ross-shire. It is impossible to compare these scattered and detached portions without imagining that the whole intervening country has once been covered with a great body of laterite, enormous masses of which have been removed by denudation. The same remarks might be applied with some modification to the subjacent sandstone. Some fragments of this great denudation may be recognised in the laterite gravel and clay, which overspreads the surface of many parts of the country, and which, when reconsolidated, it is often difficult to distinguish from the true laterite, from which it has been derived, and for which it has often been mistaken.

From Beeder to Calliany, trap and laterite.

It is now time to resume our journey towards the old Jain city of Calliany, more lately the metropolis of the * kings, a provincial city under Aurungzebe, and now under the Nizam.

From the foot of the cliffs of Beeder a plain, based on trap amygdaloid, abounding with calcedonies, zeolites, and calc spar, broken only by a few slight undulations, extends to Calliany, near which the surface undergoes a gentle but considerable ascent; a few belts of the reconsolidated laterite gravel just described cross the road resting on the trap, and are evidently derived from some high laterite cliffs to the W. and N. of the city, to which I traced the *débris*. On one of these heights stood a few denuded laterite cliffs, about twenty or thirty feet high, insulated from each other by spaces four or five feet wide, and resembling those already delineated in the Beeder valley section. A piece of calcedony was picked up in the gravel, but none could be discovered in the unfractured laterite. The trap, in the form of wacké, here underlies both the laterite and its detritus; the line of demarcation is perfectly defined and distinct.

Bazar excavated in the laterite cliffs of Calliany.

Nearer Calliany the bed of laterite gravel is succeeded by laterite, which forms a low ridge of hills immediately to the west of the town. A street has been cut from the rock running along the side, about midway up the ascent, in the scarp of which a long row of now deserted houses and shops has been excavated, and, also, small caves supported by pillars of the laterite left untouched while excavating. The bases of the cliffs in the vicinity are quarried for the softer variety of the laterite, which is carried off in baskets, ground with water into a plastic clay, and used as a water-proof covering to the tops of the flat-roofed houses of Calliany. The laterite is here called by the natives, from its worm-eaten appearance, *Kire ka putthur*, or *Silika putthur*. The Tamuls call it *Chori kulloo*, *vettie*, and *culloo;* and on the Malabar coast it is termed *Stika culloo.*

The wells here are of considerable depth. The temperature of one, 35 feet to the surface of the water, was 78° 5′; temperature of air in shade, 89°; the boiling-point of water, 206° 5′; temperature of air, 84°.

The soil between Beeder and Calliany is principally lateritic, mixed with the detritus of the subjacent trap, crossed in a few situations by zones of regur, often blended with the trap and laterite soils; the low flat-topped hills avoided by the route appear to be of laterite resting on the trap.

* MSS. illegible.

From Calliany to Gulburgah.

The laterite continues from Calliany to a few miles beyond Murbi, a distance of about fifteen miles, forming long flat-topped ranges of hills rising about a hundred feet above the general level of the table-land, and running E.S.E. They are separated by narrow, flattish valleys, having a similar direction to that of the hills, and to that of the wider valley separating the Beeder and Calliany laterite cliffs. They present the usual appearances of valleys of denudation, and in many places the trap and amygdaloid underlying the laterite have been exposed.

At Murbi the laterite table-land of Calliany is descended to a terrace or step of comparatively level land, where the trap and its associated wacké, amygdaloids, and kunkur, are the only rocks met with. A little N. of Gulburgah, another terrace, formed by these rocks, is descended to the still lower level on which the city stands in the valley of the Bhima, about twelve or fourteen miles to the north of the present channel of this fine river. About ten miles south of the city, beds of limestone outcrop from the trap between the villages of Nundipoor and Sinnoor, and continue forming the bed of the Bhima at Firozabad, dipping slightly towards the S.W. The limestone continues, on the opposite or south bank of the river, about four miles a little to the N.E. of the village of Gownully, where it is again overlaid by the trap. Plate I. Diagram, fig. 5, is a rough section from the table-land of Calliany to the south bank of the Bhima, comprehending a tract of land about fifty miles N. and S., exhibiting extensive denudation, both laterite and trap having been stripped off the subjacent limestone exposed in the valley of the Bhima. On the south side of the valley the trap re-appears, but the softer laterite has been entirely swept away.

A. Laterite.
BB. Trap once forming a continuous sheet.
C. Limestone.

Rolled and waterworn fragments of the trap occur in and on the soil and gravel overlying the limestone, at a distance of two or three miles from the present channel of the river, and far above the reach of its highest floods. The traces have all the appearance of having been formed by the action of water.

Iron smelting at Murbi.

It must not be omitted to mention that at Murbi, near the edge of the Calliany table-land and the adjacent village of Boghirry, the more ferruginous nodules occurring in the laterite are collected, roasted, coarsely pounded, and smelted. The furnace at Murbi is a small one, and capable of smelting about one Kucha maund of twelve seers *per diem*. The ore is subjected three times to the action of the fire,—twice

to reduce it and cleanse it from dross by beating the half-molten mass with heavy hammers; and the third time to form it into bars, and other forms convenient for agricultural implements, which are sent to Gulburgah and Calliany. These markets are also supplied with iron from Mogumpilly in the Koil Talook. The ore, which is in the form of nodules, often exhibits, on fractured surfaces, stripes of hæmatic red earthy ore, alternating with others of a metallic iron blue. It is sold by the people who collect it to the iron contractor on the spot at the rate of three and a half Hyderabad rupees the Kucha maund of twelve seers.

Lithologic character of the Firozabad Limestone and Traps.—The denuded limestone in lithologic character closely resembles that of Kuddapah, Kumool, Warapilly, and Talicota; no fossils were found in it. The prevailing tint is a greyish blue; strings of small spherical cavities occur in it as in the limestones just alluded to, some empty, others filled with a brown ferruginous dust.

The trap has often a porphyritic structure, imbedding crystals of a dull olive-green mineral, which in disintegration assume a greenish-brown tinge, and finally fall out, leaving cavities in the rock. They are not unlike some varieties of olivine, a mineral occasionally seen in this trap; a great development of kunkur is observed in its fissures previous to coming on to the outcropping of the limestone.

The Bhima River.—The Bhima is about six hundred yards in apparent breadth at Firozabad; its temperature, 78° Fahr.; temperature of air, 90°; approximate height of bed above sea by boiling-point, 1,730 feet. The waters were swollen and muddy from the monsoon rains (June), and running at the rate of two and a half feet per second. A tumblerful of the water deposited about $\frac{1}{12}$ * its bulk of a fine reddish brown sediment, which effervesced with dilute sulphuric acid, evidently the *débris* of the trap, amygdaloids, and limestone rocks, over which it passes. The banks are shelving, and composed of the laminar greyish-blue laminar limestone, covered with silt and regur, and their surface strewed to a considerable distance on either side with rolled fragments of agates, calcedonies, &c. marking the extent of the floods.

The bed has been hollowed in the limestone, exposing shelving surfaces of the rock, in some places perfectly bare, others covered with silt or a gravel from the size of a pea to that of an egg, fragments of trap, and limestone, calcedonies, jasper, and agates. In consequence of the disorders committed by the irregular Arab soldiery, the town of Firozabad had been almost deserted, and the *Ambikars* with their basket-boats had quitted the ferry which was now unfordable, and the water running with considerable rapidity. The village people collected a number of pumpkins, and about noon they succeeded in netting these together

* So in MSS.

and constructing a tolerable raft, with which the stream was easily crossed.

The sources of this fine river rise in the western ghàts a little to the N. and S. of Poonah ; after watering the fertile plains of the country of the Mahrattas, where its banks are famous for the breed of horses and mares, from which the hardy cavalry of this warlike race has been chiefly supplied, and, flowing south-easterly towards the Bay of Bengal, over the almost continuous sheet of the great overlying trap formation of the Deccan, it joins the Kistnah on the granite and hypogene area of Hyderabad, about fifty miles direct distance S.E. from Firozabad. It contributes to the Kistnah many of the *Pietri duri* of the overlying trap formation that are rolled along its bed over more than half the peninsula.

Trap Formation from the right bank of the Bhima to the Laterite of Inglisswara.

The trap again covers the limestone a little to the N.E. of the village of Gonnully, about four miles from the river: the latter rock is seen outcropping for the last time at the base of a low hill of trap between Gowncolly and Sunnoo. The trap is amygdaloidal, veined with kunkur, and imbedding calcedonies and calc spar.

From Sunnoo to Jyattaky the calcedony is seen both in veins and nodules, and passes into plasma ; the colour varies from the lightest tinge of apple-green to the deep hue of heliotrope into which it passes ; in some translucent varieties the colouring matter is deposed in delicate moss-like filaments ; the colouring matter of the plasma has not been exactly ascertained by chemists, but it seems to be similar to that of the heliotrope, both disappearing before the blow-pipe.* The colour of this variety of plasma, when exposed to the reducing flame, changes to a purplish white, the plasma becoming opaque and easily frangible. I have little doubt that the red spots of the variety of calcedony termed heliotrope are derived from thin beds of fine bright-red bole, which are often seen alternating with the trap, and in nests, in this vicinity.

The surface of the country to Sindaghi presents the long, low, flat, step-like elevations of trap, separated by plains along which the route lies, and running in a S.E. direction. The soil is usually the detritus of the trap and laterite, in belts and patches of a grey colour and dark red, sometimes sandy ; the vegetation stunted, consisting chiefly of the acacias, the *Cassia auriculata*, and *Hingun* thorn. On a fallen blighted acacia amid the low jungle, I observed a chameleon perched motionless with his head erect and jaws wide open, as if, indeed, making a meal of the afternoon breeze. His skin—which mimics the prevailing hues

* Perhaps silicate of iron? that of heliotrope being the red oxide ?—Eds.

of surrounding objects; blue when basking beneath a cloudless sky, and emerald when shaded by the forest's verdure, had here so strongly assimilated that of the black and ashy-white stem on which he lay, that at first I thought it was a singular excrescence of the wood itself.

A little to the N.W. of Sindaghi the summit of a ridge is observed covered with globular masses of a compact basaltic trap, underlain by a bed of the fine red clay imbedding a profusion of zeolites, also heliotrope, plasma, geodes of calcedony lined with quartz, crystals, semi-opal, cacholong, agate, and calc-spar, resting on a greenish-grey wacké. Both rocks are veined and interstratified with kunkur of a somewhat cancellar structure. The horizontal layers of kunkur are often from ten to twelve inches thick. The softer wacké and amygdaloid in weathering often leaves the harder layers of kunkur projecting from the surface. (Plate I. Diagram, fig. 7.)

A, globular basaltic trap; B, red amygdaloid; CC, kunkur layers; D, wacké.

From Sindaghi by Ipperghi to Ingleswara the aspect of the country is much the same as from the Bhima to Sindaghi, but the plains become flatter, more extensive, and more intersected by nullas. At Ipperghi the trap assumes the rich brownish-purple or chocolate hue of the trap of Bejapore, and is seen in the bed of the rivulet resting on a beautiful red zeolitic amygdaloid : the line of contact is marked and distinct. Heliotrope and plasma are less common here.

Indications of the laterite are perceived, before reaching Ingleswara, in beds of its detritus re-cemented by a brown ferruginous and calcareous paste; also, fragments of chert and a variety of limestone porphyry. As anticipated, the laterite was found capping a ridge of trap and wacké a little to the S.W. of Ingleswara, presenting a similar development of the lithomarge near the line of contact with the trap as observed at Beeder. The latter rock passes into a friable greenish wacké, and also into a dark amygdaloid, containing spheroidal cavities, often filled or lined with green earth.

The hill of Ingleswara, marked by an old tower, is principally composed of wacké penetrated by flattish, apparently compressed, veins of fibrous arragonite. On the top of the hill are scattered globular and angular fragments of basaltic trap, while, partially imbedded in the soil covering its sides, are rough, seabrous-looking blocks of a light-coloured rock, resembling altered limestone passing into chert. These blocks are mostly angular, from generally six inches to two feet thick, have a whitish exterior so rough in aspect and touch as, in these respects, to resemble trachyte; and, when fractured, the small glistening red and white calcareous crystals they imbed might at first sight be taken for those of glassy felspar. The softer and more crystalline portions of this singu-

lar rock effervesce with acids. It occurs also in detached blocks, on the wacké at the base of the laterite cliffs S.W. of Ingleswara. The rock here is more compact, homogeneous, less crystalline in structure, and exhibits dark dentritic delineations. Some fragments are partly coated with a thin bluish white enamel, which is apt to assume a botryoidal form; on its surface are seen numerous small white globules of white enamel. Among the lateritic *débris* intermingled with these blocks are interspersed numerous nodules of a black cineritious looking mineral, containing cavities filled with an impure, earthy, brown manganese; their black outer crust is often so indurated as to give fire with steel. Before the blow-pipe, *per se*, it reddens slightly and exhibits minute globules of a bluish-white enamel. The following section will exhibit the position of these blocks of cherty limestone as they occur on the sides of a valley of denudation and excavation, a mile in width. (Plate I. Diagram, fig. 6.)

A, Laterite, overlying trap at B, and stripped off at E and Bb.
B,Bb, Trap.
C, Globular basaltic trap.
DD, Blocks of whitish scabrous limestone, passing into dust; and half imbedded in lateritic gravel.
E, Valley of denudation and excavation.

The limestone has very much the appearance of the fresh-water limestone of Nirmul, Moonapilly, and Koolkonda between Gulberga and Muctul, and has evidently been broken up and altered by the basalt.

The angularity of the fragments and their little water-worn appearance prove that this bed must have been deposited and existed *in situ* at no great distance from the present locality. The blocks were not observed in the centre of the valley, from which it may be inferred that the limestone was only a littoral deposit, or that its fragments were carried away by the aqueous current by which the valley was excavated. The laterite cliffs of Ingleswara, like those of Beeder, Sondur, and on the western coast, are cavernous: one of the caves near the summit is held sacred by the Hindoos. The entrance was barred by a locked gate; it is said by the natives (*credat Judæus*) to communicate with another similar cavern on the hill of Nageswar, also said to be of laterite, about three coss to the S.W. Near the mouth is one of those remnants of the strange ophitic adoration that prevailed over great part of Southern India in the shape of an image, of which the upper portions resemble those of a young female, and the lower terminating in the coils of a serpent.* Ingleswara is famed in Hindoo annals as the place

* We have in the Museum a *double* image of this kind formed by two female busts with serpent terminations.—Eds.

where the nuptials of Buswapa, the founder of the great sect of Jungums and Lingayets, and the overthrower of the Jain dynasty of Calliany, were celebrated. The small laterite hill of *Hori Muth*, his birth place, is at a little distance.

From Ingleswara to about eleven miles S.W. of Bagwari, trap, wacké, and amygdaloid form the basis of the plain where its southern limit is again crossed to the hypogene area. A reddish felspathic zone, similar to that already noticed in the Bigapore Notes, intervenes between the trap and the gneiss, which is first seen to outcrop in the bed of a nulla between the villages of Hungraghi and Wondal, where a section is afforded showing the thinned-out edges of this great *coulement* of trap resting on and coating the reddish intervening felspar zone. This zone, or salbande, is probably nothing more than the altered gneiss.

The mica in the gneiss is replaced by hornblende, and at a little distance the gneiss passes into hornblende schist. Both rocks are highly inclined, dipping westerly; gneiss, felspathic-veined and interspersed with quartz, continues to the left or north bank of the Kistnah to Chimlaghi, where it disappears under the beds of a bluish limestone resembling that of Firozabad. The gneiss is in some situations capped by laterite fragments of a greyish blue and buff limestone; the latter crystalline and effervescing feebly with acids, and penetrated by tortuous veins of the dark chert. A few globular boulders of granite and greenstone are scattered over the low hill of Chimlaghi, out of the reach of the floods of the Kistnah. They have a rugged water-worn exterior. The hill itself is capped with a layer of kunkur, varying in thickness from a few inches to five feet, imbedding nodules of a ferruginous clay and angular fragments of a grey and dark-coloured chert, a bed of which is seen intervening between the limestone and the gneiss. The kunkur bed rests upon disturbed strata of the bluish limestone, so much broken up that it was impossible to ascertain the dip or direction of the rock. The gneiss underlying the limestone imbeds crystals of calc-spar.

From the junction of the Kistnah and the Gutpurba, near Chimlaghi, by Kulladghi, to the west of the falls of Gokauk on the eastern flank of the western ghàts, a limestone and sandstone formation, supposed to be identical with those of Cuddapah and Warapilly, extends with partial outcroppings of the hypogenes and a few patches of overlying trap and laterite. The nature of the rocks composing the summits of the ghàts immediately behind the falls of Gokauk has not been noticed. A little further south they are composed of the hypogene schists and granitic rocks, covered partially, to the sea at Goa, Vingorla, and Malwan, by laterite. North of Malwan the overlying trap is almost the exclusive rock seen to Surat. Of the geology of the Southern Muratha Country I intend speaking more fully in a subsequent paper.

On some Petrified Shells, found in the Gawilgerh Range of Hills, in April 1823. By the late H. W. Voysey, Esq., Assistant Surgeon, H. M.'s 67th Foot.*

This remarkable range of hills is called by Arrowsmith, in his last map, the Bindeh, or Bindachull (Vindhya or Vindhyáchala) hills. The same name is, however, given to a lofty range of hills on the left bank of the Godavery, as it passes through Gondwana, and also to those near Gwalior. I shall, therefore, distinguish them by the name of the Gawilgerh range, particularly as, after repeated inquiries, I have never been able to discover that they were so designated either by the inhabitants of those hills or of the neighbouring plains. They take their rise at the confluence of the Púrna and Taptí rivers, and, running nearly E. and by N., terminate at a short distance beyond the sources of the Taptí and Warda. To the southward, they are bounded by the Valley of Berar, and to the north by the course of the Taptí. The length of the range is about one hundred and sixty English miles, and average breadth from twenty to twenty-five miles.

On the southward side they rise abruptly from the extensive plain of Berar, the average height of which is one thousand feet above the level of the sea, and tower above it to the height of two and three thousand feet. The descent to the bed of the Taptí is equally rapid, although the northern is less elevated than the southern side of the range. The outline of the land is generally flat, but much broken by ravines, and by groups of flattened summits, and isolated conoidal frustra. The summits and the flat land are, generally, remarkably destitute of trees, but thickly covered by long grass. In the ravines and passes of the mountains the forest is very thick, and, in many places, almost impervious. The inhabitants are principally Goands, whose language, manners, and customs differ remarkably from those of the Hindoos. At present their chief occupation is hunting and cultivating small patches of land, which produce a coarse rice and millet. In former years the cultivation must have been very extensive, since there are the ruins of numerous hill forts and villages, which derived their chief subsistence from the surrounding lands.

Many opportunities are afforded of studying the nature of this mountainous range in the numerous ravines, torrents, and precipitous descents which abound in every part. A Wernerian would not hesitate in pronouncing them to be of the "newest floetz-trap formation"; a Hut-

* Reprinted from the Asiatic Researches, vol. xviii. p. 187.

tonian would call them overlying rocks; and a modern geologist would pronounce that they owed their origin to submarine volcanoes.

I shall not give them any other name than the general one of trap rocks, but proceed to describe them, and state with diffidence the inferences which, I think, obviously present themselves on an attentive study of their phenomena.

1*st.*—The principal part of the whole range is formed of compact basalt, very much resembling that of the Giant's Causeway. It is found columnar in many places, and at Gawilgerh it appears stratified, the summits of several ravines presenting a continued stratum of many thousand yards in length.

2*nd.*—The basalt frequently and suddenly changes into a wacken, of all degrees of induration, and, I may say, of every variety of composition usually found among trap rock.

3*rd.*—Into a rock which may be named indifferently, nodular-wacken or nodular-basalt, composed of nuclei of basalt, usually of great specific gravity, surrounded by concentric layers of a loose earthy mass resembling wacken, but without cohesion, which, on a superficial view, conveys to the mind the idea of a fluid mass of earth having, in its descent from some higher spot, involved in its course all the rounded masses it encountered, and subsequently become consolidated by drying. A very slight inspection is sufficient to detect the true cause of this appearance, which is owing to the facilities of decomposition of the outer crust, depending on difference of structure and composition. In none of the conglomerates, or pudding stones, do we observe any traces of this structure, and, as it is common to the most crystalline greenstone, porphyritic greenstone, and those rocks usually denominated syenite, there can be little doubt that it is owing to the development of a peculiar concretionary structure by decomposition. In a small ravine, near the village of Salminda, two thousand feet above the sea, I saw basalt of a perfectly columnar structure, closely connected with a columnar mass formed of concentric lamellæ, enclosing a heavy and hard nucleus. Near this ravine I had also an opportunity of observing the gradual and perfect passage of the columnar basalt into that which has been called stratified, from the parallelism of its planes,—the composition being identical, and, without doubt, cotemporaneous. These changes and passages, from one rock into the other, are so frequent and various as to render it impossible to refer the most of them to either of the rocks I have above mentioned as types. I shall, therefore, proceed to describe those which are distinctly marked and their accompanying minerals. In external appearance the columnar and semi-columnar basalt closely resembles that of the Giant's Causeway, possessing the same fracture, internal dark colour, and external brown crust. It is equally compact

and sonorous. It, however, contains, more frequently, crystals of olivine, of basaltic hornblende, and of carbonate of lime. The fusibility of each is the same. Perhaps the basalt of the Gawilgerh range more nearly resembles in every respect that of the Pouce Mountain in the Mauritius. This is, however, of very little importance, since everybody who has travelled much in trap countries knows well what great changes in composition and structure occur even in continuous masses. Among the minerals, calcedony and the different species of zeolite are rarely found in the columnar basalt, but they are of frequent occurrence in that which is semi-columnar. The wacken, or indurated clay, is as various in character and composition as the basalt, and, unfortunately, I have no type with which to compare it, as in the case of the basalt of the Giant's Causeway. Its colour varies with its constituents, but is most usually gray. It is easily frangible, very frequently friable, and is almost always porous and amygdaloidal. It appears to be composed of earthy felspar and hornblende, with a considerable proportion of oxide of iron. It is always easily fusible into a black scoria, or glass, according to the quantity of zeolite which it contains : of all the trap rocks, it abounds the most in simple minerals. They are :—

Quartz.
Calcedony and calcedonic agates, enclosing crystals of carbonate of lime.
Common and semi-opal.
Heliotrope.
Plasma, or translucent heliotrope.
Stilbite.
Analcime.
Natrolite.
Icthyophthalmite.
Felspar.
Carbonate of lime and green earth.

I have never been able to discover in it either augite or hornblende in distinct crystals. When the surface of the land is strewed with these minerals it is a certain indication that the rock beneath is wacken. With regard to the situation of this rock, I have rarely seen it on the summits of hills, but much more frequently at their basis, and forming the flat, elevated plains. I shall have occasion to advert to this rock again, when I proceed to describe the petrified shells.

The nodular basalt is, perhaps, the most common form of trap in this mountain range, as well as in other parts of India. It more commonly forms the surface than either of the rocks, and is as frequently seen on the summits as it is at the basis of the mountains. It rarely abounds

in minerals of any kind. It is the principal source of the rich, black diluvian soil of India, commonly called black cotton soil. I have little to add to the former description of it. Its external structure is sometimes beautifully developed by decomposition, since in a mass of about six inches diameter it is possible to count above twelve concentric layers, and, on striking the nucleus a slight blow with a hammer, one or two more layers are broken off. It is owing to this facility of decomposition, that the annual rains carry down such vast quantities of alluvial soil from its surface, which is, moreover, always strewed with an abundance of nuclei in various stages of decomposition. It is owing to the difficulty with which the roots of trees penetrate this rock that they are so rare on its surface, and never grow to any size; yet this circumstance does not prevent the *Andropogon contortum* and *nardus* from growing in the most luxuriant manner, which sufficiently proves the fertility of the soil.

On ascending from the *Taptí*, I observed in a nulla a group of basaltic columns, one of which was two feet in diameter, and six-sided. When near the summit of the flat table-land of Jillan, I entered on a pass formed on one side by a perpendicular section of the rock from twenty-five to thirty feet, and on the other by a rapid descent of forty or fifty. The lower part of the section, as well as the pathway, is composed of the wacken, or indurated clay, of the kind I have before mentioned, of about ten feet in thickness; lying on it is a stratum of earthy clay of different degrees of induration and purity, twenty yards in length, and of about two feet in thickness, containing great numbers of entire and broken shells. This possesses all the characters of a stratum, since the horizontal fissures are parallel, and are prolonged, with a few interruptions, through the whole extent. The accompanying sketch will serve to give a tolerably correct idea of the mode in which the stratum appears to overlie the lower rock, and to have been depressed by that which is superincumbent. The upper rock consists of about fifteen feet in thickness of the nodular basalt, or wacken, the nuclei being of all sizes. The vertical fissures, which are so remarkable in trap rocks, are prolonged from both the upper and lower rocks into the shelly stratum, although there is no intermixture of substance.

The stratum is composed of a highly indurated clay, fusible before the blow-pipe into a fine black glass, and neither it nor the shells it contains effervesce in acids. The shells are, for the most part, flattened, and belong either to the genus conus or voluta. It is not possible to conceive that so fragile a substance as a thin land-shell should have been so completely flattened without fracture, unless it had been previously softened by some mode, which at the same time produced a sufficient degree of pressure to effect its flattening.

I have attempted, in the annexed sketch, to give a representation of the degree of flattening, but I fear that it can only be well understood by the specimens themselves.

Neither the rock nor its contained shells effervesce in acids. Westward, the ground is covered by the *débris* of a shelly conglomerate, much more indurated and impregnated with green earth, exhibiting cavities and shells in relief: from the shape of the former there can be no doubt of their having once contained shells. Some of the shells are entire, but are rarely flattened. The matrix appears to be siliceous, and in some cases approaches to imperfect heliotrope. It is not fusible before the blowpipe.

I may here mention that, in a report to the Marquis of Hastings, in June 1819, I mentioned the existence of shells in trap rocks at Medcondah, at a height of 2,000 feet above the sea. The hill was composed of nodular trap, and lying on its surface were numerous pieces of siliceous stone, containing shells of the genera turbo and cyclostoma. The specific gravity of the stone varied from 2° 0′ to 2° 5′: the shells did not effervesce in acids, although some of them preserved their external polish. Internally, some of the stones appeared to pass into flint, particularly those of small specific gravity, whilst their external surface effervesced in acids. Some of the small shells were completely changed into calcedony. Specimens of these shells are lodged with the Asiatic Society.

It is a remarkable fact, that the only remains of animals hitherto discovered in India should be found in trap rocks, and under quite peculiar circumstances :—1*st*. They are found in situations where there are no indications of the former existence of lakes. 2*nd*. Both the shells and matrix are destitute of carbonic acid. 3*rd*. The former are in many instances squeezed flat without fracture, and in some cases completely commixing with their matrix.

These effects could only have been produced by the agency of heat, and, consequently, the modern theory of sub-marine or sub-aqueous valcanoes will best serve to explain the phenomena. These shells were deposited in the stratum of clay in which they are now found, and, when forced up by the mass of wacken beneath, they were, most probably, at the same time covered by the nodular basalt. Thus we have heat, to drive off the carbonic acid and soften the shells under a pressure, which assisted the process, and at the same time flattened them.

I have too numerous collateral proofs of the intrusion of the trap rocks in this district amongst the gneiss to allow me to doubt of their volcanic origin. I shall take an early opportunity of completing the history of the trap rocks of India, for which I have collected materials for several years past.

On the Geology of a portion of Dukhun, East Indies. By Lieutenant Colonel W. H. Sykes, F.R.S., F.G.S., F.L.S.*

[Read January 23, 1833.]

My personal observation of Dukhun (Deccan) and Konkun (Concan)† is not confined to the boundaries laid down in the following geological memoir; but as the rock and mineral specimens remaining at present in my possession are from Dukhun only, I have not thought it proper to extend my details beyond the limits I here prescribe to myself, although I might venture to do so from notes taken at different periods, without exposing my accuracy to question. I will, however, in closing this paper, offer a few observations on the trap and other formations of India; the amazing extent of the former not appearing to have been appreciated hitherto in European geological works.

Boundaries.

My tract ‡ is bounded on the west by the range of mountains usually denominated by Europeans the "Ghàts," from a misinterpretation of the term *Ghàt*, which simply means a pass, the proper name of this range being the "Syhadree"; on the north by the Mool river, as far as Rahooreh; on the east by a direct line from Rahooreh to the city of Ahmednuggur, and subsequently on the north-east by the Seena river until its junction with the Beema river below Mundroop; on the south-east by a line from Mundroop to the celebrated city of Beejapoor; on the south by a line from Beejapoor to the town of Meeruj; and from this place the boundary in the south-west is the Kristna and Quina rivers, to the hill fort of Wassota, situated in the Ghàts. The western boundary line extends, as the crow flies, about 144 miles; the northern, 72 miles; eastern and north-eastern, 159 miles; south-eastern, 41 miles; southern, 80 miles; and south-western, 88 miles. Agreeably to observations made by myself and the officers of the revenue survey in Dukhun, the tract lies between the parallels of north latitude 16° 45′ and 19° 27′, and east longitude 73° 30′ and 75° 53′, and, roughly calculated, may be said to comprise an area of about 26,000 square miles.

* Reprinted from the Transactions of the Geological Society of London, vol. iv. Second Series.

† With respect to the pronunciation of native words, the "*u*" is the *u* in "*hut*," and the "*a*" the *a* in "*all*."

‡ See Map.

Stratification.

Previously to entering into descriptive details, I will state, in a few words, that the whole of the country comprised within my boundaries is composed of distinctly stratified trap rocks, without the intervention of the rocks of any other formation. Whether at the level of the sea or at the elevation of 4,500 feet, in all and every part beds of basalt and amygdaloid are found alternating, whose superior and inferior planes preserve a striking parallelism to each other, and, as far as the eye can judge, to the horizon. Barometrical measurements and the course of rivers indicate a declination of the country to the east-south-east and south-east. From the town of Goreh, latitude 19°·03 and longitude 74°·05, on the Goreh river, following a mean course for the river until it falls into the Beema, and subsequently continuing a mean course for the Beema until its junction with the Seena river, the distance is about 200 miles, and the declination 671 feet: there may, therefore, be a trifling dip of the strata; but as a succession of low terraces occurs in that distance, the apparent horizontal position of the strata may be unaffected by the above difference of level.

Dr. MacCulloch, describing the overlying or trap rocks, says "these masses are generally irregular, but sometimes bear indistinct marks of stratification."* As Dr. MacCulloch's language implies the *rare occurrence* of stratification, instead of its being a distinctive feature, at least of the Indian branch of the trap family, I deem it necessary to quote the few authors who have written on Indian geology, in confirmation of the fact I have stated.†

* Classification of Rocks, p. 466.

† "These mountains (the Vindhya range), like every other in Malwa, appear to be distinctly stratified, consisting of alternate horizontal beds of basalt or trap and amygdaloid. Fourteen of these beds may in general be reckoned, the thinnest at the top, and rapidly increasing in thickness as they lower in position, the basalt stratum at the bottom being about 200 feet thick." Again, at page 327, he says: "In the upper plains of Malwa every point of view presents the same uniform and distinctly streaked appearance noticed in the Vindhya range."—*Captain Dangerfield, in Geological Notices of Malwa,* in Appendix No. 2 to Sir John Malcolm's Central India, pp. 322-327.

Dr. Voysey, in a paper on the Geological and Mineralogical Structure of the vicinity of Nagpoor, says: "From the summit of the hill of Sitabaldi the difference in the outline of the rocks eastward is very perceptible. The *flattened summits* and *long flat outline,* with the numerous gaps of the trap hills, are exchanged for the ridgy, peaked, sharp outline of the primary rocks."—*Physical Class of the Asiatic Researches,* p. 127.

In a second paper in the same work, on some petrified shells in the Gawilgerh range of trap mountains, extending for 165 miles along the left bank of the Taptí river, from its source to the city of Boorhanpoor, he describes the principal part of the range as formed of "compact basalt very much resembling that of the Giant's Causeway. It is found columnar in many places, and at Gawilgerh it appears *stratified;* the summits of several ravines presenting a continued stratum of many thousand yards in length."—*Physical Class of the Asiatic Researches,* p. 189.

Ghàts.

The Dukhun rises, by a succession of terraces or steps, very abruptly from the Konkun.* Its valleys and table-lands have a mean elevation above the sea of about 1,800 feet. The Konkun is a long strip of land from thirty to fifty miles in breadth, lying between the Ghàts and the sea; the mean elevation of this strip is less than 100 feet; but it is bristled with isolated hills, or short ranges, some of which attain an elevation equalling that of the Ghàts. Numerous shoulders or salient angles are thrown out from the Ghàts from the western or Konkun side, and by means of these the ascent to Dukhun is effected; with what difficulty will be understood when I state that the military road of communication between Bombay and Poona, up the Bore Ghàt, rises nearly 600 feet in a mile. The western portion of my tract along the crest of the Ghàts is exceedingly strong: spurs of different lengths extend from the main range to the eastward and south-east, leaving many narrow tortuous valleys between them, some of which have the character of gigantic cracks or fissures; other valleys, although occurring less frequently, when looked at from the neighbouring ranges, appear as flat and smooth as a billiard-table, even to the crest of the Ghàts, but when traversed are found to be cut up by numerous narrow and deep ravines.† Stupendous scarps, fearful chasms, numerous waterfalls, dense forests, and perennial verdure complete the majesty and romantic interest of the vicinity of the Ghàts. As the spurs extend to the east and south-east they diminish in height, until they disappear on approaching the open plains in my eastern limits, between the Beema and Seena rivers. The area of the table-land on their summit often exceeds that of the valley between them: such is the case with the spur bordering the left bank of the Beema river for forty miles from its source, occupying, in fact, the whole country between the sources of the Beema and Goreh rivers. The spurs are rarely tabular for their whole length, but narrow occasionally into ridges capped with compact basalt, and subsequently expand into extensive table-lands. The spur originating in the hill fort of Hurreechundurghur affords a good example. The fort is about eighteen miles in circumference: on the east it presents a salient angle to the neighbouring mountain; absolute contact, however, only commences at about 400 feet from the top of the scarp, leaving a gap and an extremely narrow ridge, over which lies a difficult footpath of communication between the valley of the Malsej Ghàt and that of the Mool river. The spur then widens; some lateral ramifications shoot out, on one of which is situated the fort of Koonjurghur; at the Brahmun Wareh Pass it narrows

* See Plate V.

† The valley of the Malsej Ghàt, for instance.

considerably, but not into a ridge; it subsequently expands into the extensive and well-peopled table-land of Kanoor and Parneir, twenty-four miles long by twenty broad, having diminished in height, by a succession of steps, from 3,894 feet in Hurreechundurghur to 2,866 at Brahmun Wareh, 2,474 at Parneir, and 2,133 on the terrace of Ahmednuggur. From Ahmednuggur the spur bends southward until it is finally lost in the neighbourhood of Sholapoor. It is, in fact, the margin of a great plateau, which has a mean elevation of about 300 feet above the valley of the Godavery river, and over which the rivers Goreh, Beema, Seena, &c., take their course. The basaltic caps of the ridges appear more or less columnar, from numerous vertical fissures; the weathering of these exposed rocks produces pillars, spires, towers, houses, and other forms of works of art.* Another feature of these spurs is the occasional occurrence on their table-lands of small hummocks or conical hills with a truncated apex. Dr. Voysey† mentions "groups of flattened summits and isolated conoidal frustra" in the Gawelghur trap mountains.

One of the longest of the spurs originates in the Ghàts north-west of Satarah, and runs nearly east-south-east, about 110 miles, towards Punderpoor.

The spur immediately south of Poona, on the ramifications of which are situated the formidable fortresses of Singhur (4,162 feet), Poorundhur (4,472 feet), and Wuzeerghur, adjoining Poorundhur (at nearly the same elevation), has an extent of ninety-five miles. The accompanying section (Plate V. fig. 2) represents this spur.

Valleys.

Much having been said respecting valleys of excavation, I think it may be acceptable to offer a few observations on the valleys between the spurs. I shall describe only those that present the greatest contrasts to each other.

Valley of the Mota River.—The valley of the Mota river, south of Poona, originating in a mass of hills on the edge of the Ghàts, is so exceedingly narrow, that for some miles the bases of the opposite hills frequently touch each other, leaving, at intervals, little horizontal plots, of a pistol-shot in width. These plots occur in terraces, on lower levels as they extend eastward.

Vale of the Under.—The valley of the Under river, north-west of Poona, presents a perfect contrast to the last. It is level for twenty miles, running east and west to the very edge of the Ghàts; and a person can stand at the head of the valley upon the brink of a scarp rising almost from the Konkun. Here, at the source of the river, it is nearly

* See Plate V. figs. 1 and 2 on the Konkun; and Plate IV. fig. 1.

† Physical Class, Asiatic Researches, p. 189.

six miles wide. The river Under runs down the valley 150 feet below the level of the cultivated lands.

Vale of the Baum.—The neighbouring valley of the Baum river, unlike that of the Under, originates about seven miles from the crest of the Ghàts, at a spot where the mountain masses separate into two spurs. Hence it continues level for fourteen miles, gradually widening eastward. The Baum river, like the Under, runs at a level of 150 feet below the cultivated lands; these lands, in fact, being upon one terrace, the river upon a second and lower terrace.

Vale of the Beema.—The next valley on the north is that of the Beema river. The river rises on the elevated table-land above the Ghàts, at 3,090 feet, and within the first few miles it tumbles over several terraces. The valley, for eighteen miles, is occasionally as narrow as that of the Mota river.

Vale of the Goreh.—Next on the north occurs the valley of the Goreh river, which, from the source of the river to Munchur (twenty-nine miles), is exceedingly narrow and tortuous. Here it expands into the broad horizontal plain of Kowta, ten miles wide.

Vale of the Malsej Ghàt.—In conclusion, as a contrast to the first part of the Goreh valley, I must mention the valley of the Malsej Ghàt, on the south of the Dukhun base of the fort of Hurreechundurghur. It is several miles wide, and literally as level, even to the brink of the Ghàts, as if smoothed by art. Many of the valleys of the Ghàts, particularly that of the Mool river, from the continued scarped character of the marginal mountains, and the flatness of the bottom for miles in extent, look like fosses to a Titan's fortress.

If all these valleys be valleys of excavation, the present rivers could scarcely produce such, were we to suppose their powers of attrition in operation from the origin of things even to the end of time!

Those of a fissure-like character might have resulted from the upheaving of the beds of trap from below the sea, and the consequent probable fracture of the surface; but the same explanation will not apply to those valleys associated with the preceding, broad, flat, and margined by scarped mountains, which valleys are as wide at their origin at the crest of the Ghàts, and at the sources of the rivers which run through them, as in any part of their length.

Terraces.

As the rise from the Konkun to the Dukhun is by terraces, so the declination of the country eastward from the Ghàts is by terraces; but these occur at much longer intervals, are much lower, particularly in the eastern parts, and escape the eye of the casual observer. In the neighbourhood of Munchur, on the Goreh river, there are five terraces rising

above each other from the east to the west, so distinctly marked that the parallelism of their planes to each other and to the horizon gives them the appearance of being artificial. An artificial character also pervades the form of many insulated hills; some of which, viewed laterally, appear to have an extensive table-land on the summit, but, seen endways, look like truncated cones. Conoidal frustra in the Gawelghur range have been already noticed. Other insulated hills are triangular in their superficial planes, as the forts of Teekonch (three-cornered) and Loghur.

Escarpments.

Stupendous escarpments are occasionally met with in the Ghàts. In these instances the numerous strata, instead of being arranged in steps, form a continuous wall. At the Ahopeh pass, at the source of the Goreh river, the wall or scarp is fully 1,500 feet high;* indeed, on the north-west face of the hill fort of Hurrecchundurghur, the escarpment can scarcely be less than double that height. On the other hand, the steps are sometimes effaced, and a hill has a rapid slope. This originates in a succession of beds of the softer amygdaloids, without any basaltic interstratification; their superior angles disintegrate, and a slope results. But most usually three or four beds of amygdaloid are found between two strata of compact basalt; the former disintegrates, leaving a slope, which is not unfrequently covered with forest trees, forming a picturesque belt: the basaltic scarp remains entire, or it may be partially buried by the *débris* from the amygdaloids above; but its great thickness usually preserves it from obliteration, and it rises from the wood below with majestic effect, its black front being finely contrasted with the rich and lively green of its sylvan associate. It is these strata, arranged in slopes and scarps repeated three or four times, and so commonly met with in insulated and other mountains in Dukhun, that constitute the amazing strength of the hill forts of the country, leaving a succession of natural walls encircling a mountain. This feature did not escape the observation of Captain Dangerfield in Malwa, who says, "From the great difference in the resistance made to decomposition by these trap and amygdaloid beds, their exposed ends acquire a very distinct degree of inclination and character; the amygdaloid forming a great slope, and affording a loose mould covered with vegetation, the trap retaining its original perpendicularity and dark bareness."†

In the alternation of the strata there does not appear to be any uniformity; but the general level, thickness, and extent of a stratum are preserved, as in sedimentary rocks, on both sides of a valley; the basalt and hardest amygdaloids being traceable for miles in the parallel spurs

* Plate V. fig. 1. † Malcolm's Central India, Appendix, p. 322.

or ranges; but the imbedded minerals, and even the texture, vary in very short distances.

Columnar Basalt.

A great geological feature of Dukhun is the occurrence of columnar basalt. The basalts and hardest amygdaloids run so much into each other that the line of separation is not always readily distinguishable, excepting of course the lines of horizontal stratification. I observed the prismatic disposition more marked and perfect in the basalt strata than in the amygdaloids, and the more or less perfect development of determinate forms was dependent on the compactness and limited constituents of the rocks. Basalts and amygdaloids, however compact, with many imbedded matters, rarely formed columns. Perfect columns were generally small, of four, five, or six sides; but the prismatic structure sometimes manifested itself in basaltic and amygdaloidal columns many feet in diameter. A bare mention of the places where they occur will testify to their extended localities.

On the low table-land of Kurdah near Serroor, between sixty and seventy miles east from the Ghàts, columnar basalt occupies an area of many square miles. Small columns are seen in most of the slopes of the very narrow sinuous valleys of the flanks of the platform, and frequently the tops or terminal planes of columns are observed on the table-land forming a pavement. The perfect columns in the flanks are generally small, four, five, or six-sided, and rest on a stratum of basalt or amygdaloid. In some spots the columns are articulated, in others not. In a mass of colnmns in the face of the table-land towards Serroor the columns are of different lengths, but spring from the same level. More articulations having been washed from the outer columns than from the inner by monsoon torrents dashing over them, a pretty flight of steps remains. The columns of this table-land are for the most part erect, but sometimes stand at various angles to the horizon, usually at 45°. In one instance, near the village of Kurdah, they lean from the east and west, towards a central upright mass: these are about fourteen feet in length, and are not articulated. In a mass of columns facing the west, and two miles south of the cavalry lines at Serroor, some are bent and not articulated; they are, nevertheless, associated with straight columns, which are articulated. At Karkullah, thirty miles north-west of Poona, between Tellegaon and Loghur, a hill has been scarped for the great military road. Very numerous small columns occur in the escarpment, and they lie piled upon each other in a horizontal position; the only instance of the kind within my knowledge in Dukhun. Two or three hundred yards west of the village of Yewtee, Purgunna Kurdeh, in the rocky banks of a rivulet, imperfect columns are seen. On the right

bank they are so marked as to have excited the attention of the natives (an unusual event); and they are daubed with red lead, in the manner of Hindoo deities, and venerated.

At Kothool, twenty-two miles south of Ahmednuggur, there is a thick stratum of close-grained gray homogeneous basalt in the face of the hill on which is seated the temple of Khundoba. Vertical and horizontal fissures are seen in the lateral plane or exposed edge of this stratum, but they are so far from each other as to leave huge blocks between them, giving the appearance of the superstratum of the hill being supported by massive articulated pilasters. Parts of the exposed edge are detached from its mass, leaving rude columns four or five feet in diameter, eight or ten high, and composed of three or four weighty stones disposed to assume geometrical forms. In the watercourses near Kurroos, Turruf Ranjungaon, columns are observable. The basalt is bluish gray, compact, has a vitreous hue and sharp fracture. The columns occur very abundantly in the slope of the hills, on either side of a very narrow valley running westward from the village of Ankoolner, Ahmednuggur Collectorate. They are five or six-sided, articulated, and from a foot to two feet and a half in diameter, and of various lengths; the lateral planes perfect, but in some instances the sharpness of the angles has been affected by weathering. The texture is close-grained, colour almost black, and they affect the needle.

At Jehoor, near the source of the Seena river, in an insulated hill, an obscure columnar disposition is met with in a rock, in which in other places I had not seen the slightest trace of it. A stratum of red, cellular, amygdaloid, fifteen feet thick, has sub-columns in its exposed edges eight or ten feet in diameter. In the banks of a watercourse running into the Hunga river, half a mile east of Parneir, on the elevated table-land between the cities of Ahmednuggur and Joonur, basaltic columns are very numerous; they are five or six feet high, not articulated, and are not quite perpendicular. This formation is evidently extensive, as the ends of columns, chiefly pentangular, appear in the bed of the watercourse for some distance, forming a pavement of geometrical slabs. The ends of columns of different lengths also appear in the southern bank at intervals, forming flights of steps. The basalt of which these columns are composed is very close-grained, almost black, with shining specks of a metallic lustre. The rocky banks of the Kokree river at Jambut, in the plain of Joonur, exhibit a strong inclination to a large columnar structure. In the hill fort of Singhur, at an elevation of 4,162 feet, at the western end of the fort, there is a sheet of rock which has the appearance of a pavement of pentangular slabs. The slabs are no doubt the terminal planes of basaltic columns. The same is observed in the hill fort of Hurreechundurghur, about seventy miles north of Singhur; also

in the bed of a watercourse one mile north-east of Barlonee, near the fortress of Purrunda, 112 miles east-south-east of Singhur; and, lastly, in the bed of the Mool river at Gorgaon, Poona Collectorate. These pavements extend to Malwa, as Captain Dangerfield mentions their occurrence in the beds of the Chumbul and Nerbuddah (Nermada) rivers.* The other localities of basaltic columns, or a marked disposition to this structure, were in a well at Kumlepoor, between the fortress of Purrunda and Barlonee, near the left bank of the Seena river; at Kheir, Turruf Raseen, in the face of a headland, abutting on the Beema river, on which the town stands in the ascent to the temple of Boleshwur, Turruf Sandus, Poona Collectorate; and, finally, in the scarps of a mountain running down into the Konkun, and seen from the Naneh Ghât, about three miles distant. Here the Giant's Causeway in Ireland is brought to mind; but the scale of the mountain is infinitely more magnificent, being fully 400 feet high. There is a double row of columns; but from their inaccessible situation I could only examine them through my telescope, and cannot testify, therefore, to their perfect development; but the accompanying sketch (Plate VI. fig. 1) will give a just idea of their appearance to me.

Captain Dangerfield only once speaks of columns. They lie about a mile from the Nerbuddah (Nermada), between Mundleysir and Mhysir, at 696 feet above the sea: they are either vertical or highly inclined. General Hardwick has published a lithographic sketch of them.† I have already stated that Dr. Voysey found columnar basalt in many places in the Gawelghur range.

Schistose Structure.

Following the preceding formation, I may mention, that in some few places a schistose structure was met with; but its extent was limited to a few yards, the lamellæ were vertical, from an inch to three inches in thickness, being perfect tables, with parallel bounding planes. The rock in which this structure occurs is a simple, indurated, gray clay, which flies into fragments under slight blows from the hammer. At Dytneh near Serroor some very perfect specimens have led the inhabitants to connect mystic influences with so artificial a development of inorganic matter. The spot is daubed with oil and red lead, and venerated.

Basalt en boules.

Another characteristic feature is the general diffusion of those rounded or oval masses of compact basalt, with concentric layers like the coats of an onion, which the French geologists denominate "Basalt en boules," and ourselves nodular basalt.

* Malcolm's Central India, Appendix, pp. 329, 330.

† Ibid, p. 323.

These concretions are usually found at the base of hills, buried in the *débris* from the decomposing strata; but in the Konkun, between Choke and Campolee (the latter at the foot of the Bore Ghàt), two villages on the high road between Bombay and Poona, I met with them lying on the surface over a considerable area. They occur in a similar manner on the table-land of the ball-practice hill at Poona. At Koothool (already mentioned), in the slope of the hill, and in the *débris* at its base, and along the edge of the table-land near Paubul, they are abundant; but the finest specimens are seen near the village of Karkullah, thirty miles north-west of Poona, associated with horizontal basaltic columns. The hill has been cut away, to form the great military road. In making the escarpment the balls were met with, and it being impossible to cut through the nuclei in vertical sections, it was either necessary to leave them projecting or to remove them altogether: in the latter case cavities remained equal to the hemispheres of the nuclei; and the vertical sections display from ten to fifteen concentric layers of friable gray stone, which in some instances I have found to affect the needle. I compared specimens of the nuclei with a mass brought by me from the Solfatara at Naples, and found them quite similar in aspect, colour, hardness, and great weight. This formation excited the attention of those gentlemen who have visited the northern and eastern parts of the great trap region;* but Dr. Voysey was quite mistaken in supposing it formed the basis of the Western Ghàts. Captain Coulthard speaks of it in Sagar.† Major Franklin also noticed it in the trap of Sagar, in lat. 23° 51′, and long. 78° 44′, at 1,933 feet above the sea, as "frequently globular; the nuclei of the decaying masses varying in size from an egg to a large bomb-shell, and their decomposing concentric lamellæ being generally very thin, and often very numerous."‡

Dikes.

I now pass to the basaltic dikes, several of which came under my notice in different parts of the country. They are all vertical, and I did

* Dr. Voysey says, "The nodular wacké or basalt is one of the most common forms of trap in the extensive districts composed of the rocks of the family south of the Nermada (Nerbuddah) river. It occurs perpetually in the extensive and lofty range of mountains (the Gawelghur) situated between the Purnà and Taptí rivers, and appears to form their principal mass. It is found equally abundant throughout the whole of Berar, part of the provinces of Hyderabad, Beeder, and Sholapoor, and appears to form the basis of the great western range of trap hills which separate the Konkun from the interior of the Dukhun."—*Physical Class, Asiatic Researches*, pp. 126, 189.

† "The base of the hills is invariably broader than the summit; and if the sides of a hill are smooth and even, *balled* trap, often a concentric lamellar variety, will be the principal component matter, decomposing and decomposed into a predominating workable clay, still showing the parallel converging layers."—*Ibid*, p. 78.

‡ Ibid, p. 30.

not observe that they occasioned any disturbance or dislocation in the strata of basalt and amygdaloid, through which they passed.

Two dikes run obliquely across the valley of Karleh (35 miles north-west of Poona), and intersect each other; they are about four feet thick and cut amygdaloidal strata. A prismatic disposition is generally observable in the fracture, and from one of them I obtained a square prism, which lay at right angles to the walls of the dike. The texture is compact. The military road running through this valley and down the Bore Ghàt to Panwell is frequently crossed by ridges which I presume to be the outcrops of dikes. A dike is seen on the southern slope of an insulated hill, near the villages of Bosree and Digghee, 7½ miles north of Poona.* It is about four feet thick, has a transverse prismatic fracture, is compact, and runs from the bottom to the top of the hill; but it is not discoverable in the northern slope. It is visible from the cantonments at Poona. A similar dike occurs in the hill at Ombreh, twenty miles north-north-west of Poona. But the most remarkable dike runs vertically, from east to west, through the hill fort of Hurreechundurghur. It is first seen, of a thickness of six or seven feet, in the ascent of the mountain on the south-east from Keereshwur, about 400 feet below the crest of the scarp. The path of ascent into the fort is intersected by it, and its prismatic fracture, at right angles to its planes, offers a few available steps in the ascent. It is traceable for about 300 feet in perpendicular height. On the top of the mountain, within the fort, about a mile to the westward, it is discoverable at intervals, cutting through basaltic and amygdaloidal strata. I could not ascertain whether or not it appears in the western scarp of the mountain, the point to which it directs its course being wholly inaccessible.

The gentlemen whose geological memoirs I have quoted rarely advert to the subject of trap dikes, and their notices are very brief. Captain Dangerfield says, "The trap of the southern boundary of Malwa is much intersected by vertical veins of quartz, or narrow seams of a more compact heavy basalt, which appears to radiate from centres."† Beyond the continuous trap region of the peninsula, Dr. Voysey notices a basaltic vein in syenite, near the Cavary river at Seringapatam, which must have been propelled upwards, as it broke through an oblique seam of hornblende in the syenite, and carried the pieces up above the level of the hornblende vein.‡ "On the eastern coast," Mr. Calder says, "from Condapilli northward, the granite is often penetrated and apparently heaved up by injected veins or masses of trap, and dikes of greenstone."§

* See Plate V. fig. 1.

† Malcolm's Central India, Appendix, p. 330.

‡ Physical Class, Asiatic Researches, part i. p. 22.

§ Ibid, part i. p. 10.

Ferruginous Clay.

The next distinctive feature is the occurrence of strata of red ochreous rock, in fact, MacCulloch's ferruginous clay underlying thick strata of basalt or amygdaloid, precisely as is seen to be the case in the Giant's Causeway in Ireland. It passes through every variety of texture, from pulverulent, friable, and indurated, to compact earthy jasper. The stratum is from an inch in thickness to many feet. The rock makes a red streak on paper, with the exception of the very indurated kinds, and does not affect the needle. It is pulverulent near the basaltic columns at Serroor, friable under sub-columnar red amygdaloid, near the source of the Seena river, indurated under basalt at Kothool. Although hard, it is here so cellular as to have the appearance of sponge, and, reduced to powder, looks like brickdust.

In the scarps of the hill fort of Hurreechundurghur and a mountain near Joonur, in which are excavated numerous Boodh cave temples, it is found compact and homogeneous, and is, in fact, an earthy jasper. In these localities it lies under from 300 to 600 feet of basalt. In the former locality it is about three feet thick, in the latter one foot. At Nandoor, north-north-west of Ahmednuggur, in the valley of the Godavery river, it is found as a porphyritic stratum many feet in thickness, and is used as a building stone. The imbedded matter consists of very minute crystals of lime. At Wangee, lying nearly in the latitude of Barlonee, but differing 18 miles in longitude, and at Barlonee, it occurs as an earth; as both places lie on the same level, I have no doubt the stratum is continuous between them. It occurs abundantly in the Ghàts, frequently discolouring the rivulets, and giving a ferruginous character to the soil over a considerable area. When thin, and under heavy beds of basalt or amygdaloid, the exposed edge of the stratum projects, is rounded, and double the thickness of the stratum itself, as if it had once been in a tenacious fluid state, and squeezed out by the superincumbent basalt. Such is the case at Jehoor, and an illustrative specimen accompanies this paper.

Pulverulent Limestone.

Limestone is met with, in the Dukhun, only in three states: pulverulent, nodular, and crystalline. The first occurs in thin seams on the banks of rivers and watercourses and at the base of hills in *débris*. The seams are from an inch to three feet in thickness, covered by a few feet of black earth. Sometimes in whiteness it resembles pounded chalk, and is then used by children to smear their writing boards.

In this state it occurs at Jehoor and Islampoor, near Ahmednuggur. At Kurkumb and at Salseh, ten miles south of the fortress of Kurmaleh,

it is met with under black earth in unusually thick strata, and of a peculiar whiteness. Major Franklin notices "a stratum of earthy limestone, white as chalk, at Sagar, occurring under a stratum of amorphous trap."*

Nodular Limestone.

The nodular limestone, which is the well-known kunkur† of India (*kunkur* being a native word for nodule), occurs, like the preceding, disseminated or diffused in the soil, and also on the surface. I have never seen the nodules of a regular crystalline form. They vary in size from a marble to a twelve-pound shot, and many of them are exceedingly irregular in shape, particularly those dug from the banks of rivers. They are sometimes obscurely lenticular. They are so abundant in certain localities that they appear as if showered upon the earth, and disguise its colour. Dr. Buchanan mentions the same in Rajmahl. When upon black soil they are usually minute and tolerably uniform in size; on other soils their form is variable. In the Ghàts neither pulverulent nor nodular lime is met with. It is unnecessary to particularise the localities of the nodular kind, as it is of common occurrence eastward from the hilly tracts of the Ghàts, and is the only source of lime for mortar, a class of persons making a livelihood by collecting the larger nodules. When carefully burnt, they make an excellent cement. Captain Dangerfield describes "the occurrence (in Malwa) in some parts, particularly near the bottom of the small hills and banks of the rivulets, of a thin bed of loose marl or coarse earthy limestone."‡

Captain Coulthard says, "In Sagar a white patch of this limestone mouldering by the weather is the source from whence comes the particles of kunkur, mixed with the black basaltic earth of the neighbouring valley, in such proportion as to add increased fertility to it; and if a rivulet meanders through that valley (and such is generally the fact), patches, made up of aggregated particles of the same, will here and there be found; and this it is which the native families pick out and work into lime."§ Captain Coulthard refers the origin of the nodules to limestone rock underlying basaltic strata, but I cannot trace them to such a source, not having seen strata of compact limestone, properly so called, in the Dukhun. The only specimen of compact limestone met with by me was in the bed of the Beema river near Pundurpoor. It was an insulated, amorphous, gray mass, four or five feet in diameter. I looked upon it as an aggregation of the pulverulent particles of the

* Physical Class, Asiatic Researches, part i. p. 30.

† The Mahratta word is not spelt with an "a."

‡ Malcolm's Central India, p. 328.

§ "Trap of the Sagar District," Physical Class, Asiatic Researches, p. 60.

lime disseminated in the neighbouring banks. A specimen of it accompanies this paper.

Crystalline Limestone.

Lime in a crystalline state occurs only as an imbedded mineral in the amygdaloidal strata, in quartz geodes, and in the nucleus or compact part of masses of mesotype or stilbite. It is rare compared with the preceding varieties.

Loose Stones.

Another feature of Dukhun is the occurrence of immense quantities of loose basalt stones, as if showered upon the land ; also masses of rock heaped and piled into mounds, as if by the labour of man. Their partial distribution is not less remarkable than their abundance. For the most part, the stones have a disposition to a geometrical form, and it is by no means rare to meet with prisms of three or four sides and cubes almost perfect : stones with one or two perfect planes are very common. Their texture is close-grained, and the colour verging to black.

At Dehwuree, Hungawaree, Behloondee, Kothool, and Dytneh, in the Ahmednuggur Collectorate, they are very abundant. At the last place they cover fields several acres in extent so thickly that the black fertile soil on which they rest is not discoverable : they vary from an ounce to several pounds in weight. Amongst these I picked up a perfect square prism. In neighbouring fields, most unaccountably, there is not a stone to be seen : patches of sheet rock occur in their vicinity. Other localities are the top of the Neem Durra Ghàt near Ahmednuggur ; the junction of the Beema and Seena rivers below Mundroop ; right bank of the Seena at Kurmaleh ; between Kurjut and Meerujgaon ; and generally it may be stated that the precipitous slopes of the low table-lands of the Desh (open or flat country) are very strong and rocky. For ten miles between Jeetee and Soagaon, Ahmednuggur Collectorate, the fields, and even the road, are so thickly strewn with large basalt stones as to render cultivation difficult and travelling penible.

Rocky Heaps.

The singular heaps of rocks and stones above noticed occur at Kanoor, Patus, Kheir, between Kurjut and Meerujgaon, and at other places in the Desh, but not in the Mawals, or hilly tracts of the Ghàts. The heaps are from twenty to seventy feet in diameter, and the same in height : when composed of rocky masses without small stones, blocks of three or four feet in diameter and with a disposition to determinate forms, are piled upon each other, constituting rude pillars. In certain parts of the country from fifty to sixty of these heaps are seen within the

area of a couple of square miles, and it excites surprise that the intermediate ground is destitute of stones.

Sheets of Rock.

Mention must not be omitted of the constant recurrence of sheets of rock of considerable extent at the surface, and totally destitute of soil; this is particularly the case in the Mawals, or hilly tracts along the Ghâts. They abound with narrow vertical veins of quartz and chalcedony. When of sufficient thickness, the vein splits in the centre, parallel to the surface of its walls, the interior being drusy with quartz crystals: the walls consist of layers of chalcedony, cachalong, hornstone, and semi-opal. These veins supply the majority of the siliceous minerals so abundantly strewed over Dukhun.

The localities where the sheets of rocks particularly struck me were Lakungaon, on the plain of Joonur, and generally in the valley of the Goreh river; at Kothool, Purgunna Kurdeh; at Kheir and Raseen; in the hill fort of Hurreechundurghur; most markedly between Kooldurrun and Pairgaon on the Beema river. At Aklapoor, on the Mool river, they were very extensive; and at Angur, Mohol, Kurjut, and Patkool. Generally, in the eastern and south-eastern parts of my tract, much decomposing amygdaloid is found at the surface of the low table-lands or terraces, which, in favourable monsoons, is equal to the support of Jowaree;* but a small deficiency in the rains occasions the destruction of the crop.

Structure and Mineral Composition of the Trap Rocks.

The structure and mineral composition of the trap rocks in Dukhun vary exceedingly in short distances, even in the same stratum; nevertheless the predominant character does not disappear, although the basalt in a continuous bed may pass several times from close-grained, compact, and almost black, to gray, amygdaloidal, and externally decomposing. The same observation applies to the amygdaloids. A variety of compact basalt, of an intense green colour, is susceptible of a brilliant polish, and rivals the celebrated Egyptian kind. It is of great weight and remarkable hardness: the natives use it to work into idols for their temples, pedestals to the wooden columns in their mansions, and slabs for inscriptions. The bulls of the size of life, always placed before the temples of Mahadeo, are cut out of this variety at Raseen, Wurwund, and the renowned Boleshwur. Some of the pedestals in the gateway of the Mankeswur palace at Teimboornee look like mirrors. In the temple at Pooluj, south of Punderpoor, there is a slab six or seven

* Andropogon Sorghum.

feet long and 2½ broad, covered with an inscription in the Kanree language; and in Punderpoor the streets are paved apparently with the same basalt. At Jehoor, and near Ahmednuggur, is found a compact kind like the last, but not so heavy. It has a crystalline character and sharp fracture, and has angular siliceous pebbles imbedded: an occasional pebble is loose in its cell. In the Happy Valley near Ahmednuggur the basalt is compact and smooth, with reddish, flat, transparent crystals imbedded. It opposes a feeble resistance to the hammer, and flies into fragments, some of which have right angles. The basalt, even of the true columns, is not of a uniform texture in different localities: at times it is blackish or gray, and very small, granular or compact; at others, earthy and ferruginous, particularly externally. The basis of the amygdaloids is clay, with more or less hornblende disseminated: they embrace the cellular, porphyritic, hard, friable, and decomposing. I endeavoured to class them agreeably to the prevalence of quartz, chalcedony, lime, mesotype, or stilbite, as imbedded minerals, but found the method of very limited application. Sometimes one mineral only is imbedded, occasionally two, and often the whole.

In Hurreechundurghur quartz amygdaloid prevails: at Aklapoor, on the Mool river, it is characterised by mesotype, that mineral being imbedded in large masses, and the radii (six or seven inches) are the longest I have seen. At Nandoor it is porphyritic with minute crystalline specks of lime: near Ahmednuggur is seen a cellular, indeed spongiform kind, which is hard, and the cells are empty. A small cellular and pisiform variety is found in the wonderful cave temples of Ellora, and some of the sculptured figures appear as if marked by the small-pox. This observation is partially applicable to the Boodh and Hindoo cave temples of Elephanta, Salsette, Karleh, Joonur, the Naneh Ghàt, and the Adjunteh Ghàt; all of which are excavated in basaltic or amygdaloidal strata. The stilbite or Heulandite amygdaloid is of very common occurrence; but the most prevalent kind is that in which all the minerals noticed above are associated. The stone usually selected for building is of various shades of gray or bluish gray; has hornblende disseminated in very small crystals, works much easier than some of the compacter basalts, but takes a good polish. The entire temples of Koorul and Boleshwur, with their innumerable alto-relievo figures and laboured ornaments, are built of this variety of trap, which is, in fact, a greenstone, although less crystalline than the European rock. There is a variety selected carelessly, also used in building, which has the structure and nearly the external characters of the last, but which, in weathering, exfoliates, and the buildings fall to ruin; such is the case with the great temple in Hurreechundurghur.

I must not omit mention of two remarkable rocks which, as far as my

reading extends, have not been noticed by authors on European geology. The first is an amygdaloid in which compact stilbite is imbedded in a vermicular form. One of its localities is the insulated hill on which stands the temple of Parwuttee in the city of Poona;* and it is met with in many other places. Captain Dangerfield observed the same peculiar stratum near Sagar. He says, "There occurs an amygdaloidal or porphyritic rock, consisting of a compact basis of wacké, in which are imbedded, in great abundance, small globular or uniform masses, but more usually long *curved* cylindrical or vermiform crystals of zeolite."†

The other rock occurs as a thick stratum of amygdaloid at the elevation of 4,000 feet, in the hill forts of Hurreechundurghur and Poorundhur; and in the bed of the Goreh river at 1,800 feet, near Serroor. The matrix resembles that of the other amygdaloids, but the mineral imbedded is a glassy felspar in tables resembling Cleavelandite, crossing each other at various angles, and so abundant as to occupy a moiety of the mass. I have only remarked it in the above localities, and it does not appear to have come under the notice of the gentlemen I have so often quoted in other parts of the Peninsula.

Minerals.

Minerals are not uniformly dispersed in Dukhun. In one part quartz predominates, in another chalcedony; and these are more or less associated with jaspers, agates, hornstones, heliotrope, and semi-opal or cachalong. In other places particular members of the zeolite family prevail, nearly to the exclusion of the siliceous class; and elsewhere there is a diminution of minerals amounting almost to privation. Amethyst quartz is rare in Dukhun; when met with it constitutes the crystal lining the interior of geodes of agate. I have not seen it in veins. Pseudomorphous quartz is common; the most frequent impression is that of rhomb spar. Lime occurs only in three crystalline forms: rhomb, dogtooth, and the dodecahedron. The first is found on the surface, and imbedded in masses of quartz and compact mesotype; the two latter forms are associated with ichthyophthalmite in cavities in the amygdaloid strata.‡

The following are a few of the mineral localities:—

At Kothool, south of Ahmednuggur, the numerous quartz and chalcedony veins cover the country with agates, colourless quartz crystals, and chalcedony; some of the specimens are fully a foot thick, in-

* See Plate V. fig. 2, near to the city of Poona.

† Central India, p. 328.

‡ That comparatively rare European mineral, ichthyophthalmite, is most abundant and of great beauty in the neighbourhood of Poona.

cluding both walls of the vein. Here are met with some few crystals of calcareous spar enclosed in quartz. At Ahmednuggur, to the above siliceous minerals some members of the zeolite family are to be added, principally stilbite. At Nandoor, on the plain of the Godavery river, the zeolites disappear, and the siliceous minerals are limited in number. On the contrary, at Jamgaon, eighteen miles west of Ahmednuggur, on the upper terrace or plateau, in addition to all the minerals enumerated, bits of yellow and red jasper and heliotrope occur. Ascending the Mool river from Nandoor, at Aklapoor, great masses of mesotype, with radii several inches long, are found imbedded in friable amygdaloid. North of Aklapoor, at Gorgaon, a new mineral occurs in a mass two feet in diameter. Its depth I do not know, as it lay partly buried in the amygdaloid bed of the river: its colour green, and breaking into rhombs. Gorgaon is the only locality known to me of this mineral. Its measurements are those of calcareous spar, but the specific gravity is less. It is stated to be coloured by green earth. It is interesting from being unknown in the cabinets in England.

A few miles further up the Mool river, at the village of Chas, in the shoulder of a hill formed of numerous thin horizontal beds of decomposing amygdaloid, many specimens of cloudy calcareous spar, imbedded in stilbite, are found, and the siliceous minerals are rare. Ascending to the source of the river the same scarcity prevails. Three miles south-south-west of Chas, at Brahmunwareh, great masses of stilbite, of the radiating foliate kind, are imbedded in hard amygdaloid. In the hill fort of Hurreechundurghur, although siliceous minerals are not abundant, crystallised quartz of various colours is seen, a feature not characterising the Desh or open country. South of Ahmednuggur, as far as Soagaon on the Beema river, and Meerujgaon on the Seena river, the Ahmednuggur minerals prevail; hence, descending the Beema to its junction with the Seena, a gradual diminution takes place, and at the junction they almost disappear; returning north, at Ashtee, between Kurkumb and Mohol, a few are met with. At Oondurgaon, and up both banks of the Seena river to Purrunda, numerous and very fine specimens of milk opal, with a flame-coloured tinge in transmitted light, are found on the surface; and this is the only locality where I met with opal as a distinct mineral; and here the members of the zeolite family are very rare. At Tudwull, between Oondurgaon and Barlonee occur the only specimens of black calcareous spar seen by me in Dukhun; it is associated with transparent calcareous spar. In excavating wells in the cantonments at Poona, splendid specimens of ichthyophthalmite were brought to light; and generally in the bed of the river Mota-Mola and the neighbourhood, fine specimens of heliotrope and coloured quartz occur. The other minerals are *nadelstein*, *analcime*, *chabasite*, and

laumonite. Captain Dangerfield's details prove that the minerals of Malwa are identical with those of Dukhun.

Natural Salts.

Only two kinds of natural salt came under my notice, namely, muriate and carbonate of soda.

With respect to the former, many of the wells at Ahmednuggur are brackish; and there is a rivulet running into the Seena river about two miles north-west of the city, which has its source a few miles distant, called the Salt Brook. It passes over a saliferous soil; and in its dry bed, or on insulated stones standing in its stream, are incrustations of common salt intimately mixed with carbonate of lime. No use is made of this salt. The saline impregnation of the soil extends to some distance west and north-west of Ahmednuggur, as I found a handsome well at Kurjooneh, eight miles distant, filled with water so brackish as not to be available for domestic use. At Wurgaon, between Kurjut and Pairgaon, a peculiar hoary appearance of a patch of ground in the midst of withered grass led me to examine it. The whiteness was occasioned by lime in minute particles, mixed with a little muriate of soda.

The third locality of common salt was in the bed of a rivulet at Koond Mawlee, near the falls on the Kookree river, between Serroor and Kowta. A little common salt, with a trace of carbonate of soda, appeared, encrusting the rocky bed for a few feet near the water line. I did not observe common salt elsewhere. My attention was first directed to carbonate of soda at Serroor, by observing washermen digging for earth in the banks of a rivulet; learning that they used it to wash their clothes, I obtained a quantity, lixiviated the earth, boiled down the lixivium, and on cooling obtained a large crop of crystals, which the usual tests indicated to be carbonate of soda. I only met with one other bed, although I have no doubt they are numerous. At Kalbar Lonee, twelve miles east of Poona and two miles south of the Mota-Mola river, within an area of 200 yards, a constant moisture and partial absence of vegetation is observed. An efflorescent matter appears on the surface every morning, which is carefully swept up and sold to washermen: it is carbonate of soda. The occurrence of salts in the trap formation did not escape Captain Dangerfield's notice. He states that "the banks of the Nerbuddah (Nermada) near Mundleysir, consist of an upper thin bed of vegetable mould; a central bed, chiefly of indurated marle, strongly impregnated with muriate of soda; and a lower bed, of a reddish hue, with much carbonate of soda. In the dry season these salts form a thick efflorescence on the surface of the bank."* Saltpetre is manufactured

* Malcolm's Central India, p. 324.

in Dukhun, not from nitrated soils, but from the scrapings of old walls. I have also seen specimens of muriate of ammonia obtained by the brick and tile-makers in burning dung, stable and other refuse matters in their kilns.

Ores.

No other ore than that of iron is found in Dukhun. It is only worked, to my knowledge, at Mahabuleshwur, at the source of the Kristna river. It occurs as a nodular hematite, associated, I understand (for I have not been at the spot myself), with laterite. This ore produces the celebrated Wootz steel.

Organic Remains.

I did not meet with organic remains of any kind whatever. Captain Coulthard* in Sagar, Major Franklin in Bundelkand, and Captain Dangerfield in Malwa, were equally unsuccessful. Dr. Voysey, indeed, mentions a bed of fresh-water shells in a stratum of indurated clay near the Tapty river in the Gawelghur hills; also at Medconta 2,000 feet above the sea, on trap; but these may have been recent, as he does not say to the contrary.† Mr. Calder, in his general observations on the Geology of India,‡ says, "But hitherto the most striking phænomenon in Indian geology is the almost total absence of organic remains in the stratified rocks and in the diluvial soil." As this must have been written with a knowledge of Dr. Voysey's paper, it being in the same volume with his own, it is probable he considers the shells recent.

Thermal Springs.

Thermal springs do not exist in Dukhun within my limits; but there are three distant localities in the Konkun below the Ghàts, where hot water gushes up from numerous crevices in trap rocks over an extensive surface.

The first is at Vizrabhaee, forty-eight miles north of Bombay, where the principal springs are in the bed of a river, and in the monsoon are consequently lost in the swollen stream; but in traversing the jungle in the vicinity I have met with detached pools of hot water, which are unaffected by the rains; their temperature is very high. The second locality is that mentioned by the late Dr. White, of the Bombay army. The hot wells are called Devakl Unei, and are fifty miles south-east from Surat,§ at the foot of some hills; the temperature in the different springs ranges from 111° to 120° Fahr. They are spoken of as being in the vicinity of Anaval and Veval, but as these places, agreeably to

* Physical Class, Asiatic Researches, p. 81.
† Ibid, p. 194.
‡ Ibid, p. 16.
§ Transactions of the Royal Asiatic Society, 1833.

the map of India, are only thirty miles from Surat, there is evidently some mistake with regard to the distance. The third locality is at Mahr, on the Bancoot or Fort Victoria river, about seventy-five miles south of Bombay. I know of these springs only from report. The whole of the above springs, extending through 3° of latitude, lie nearly in the same parallel of longitude (73°), and are within twenty-five miles of the sea.

In a manuscript report to the Government of Bombay, on the province of Khandeish, Colonel Briggs has the following passage testifying to the occurrence of thermal springs above the Ghàts:—

"Among the natural curiosities of Khandeish are the hot springs of the Satpoora hills, particularly those of Soonup Deo and Oonup Deo, the former in the district of Arrawud, and the latter in the deserted Purgunna of Amba. The former is so hot that the hand cannot be borne in it; the latter is less ardent, and is used as a hot bath; they are both said to possess medicinal qualities, and are considered useful in the cure of cutaneous disorders,—amongst others, leprosy."

Dr. Buchanan speaks of hot springs at Rishikunda and Bhimband in the trap mountains of Rajmahl;* and the Rev. Mr. Everest mentions a thermal spring associated with a trap bed at Kateamsan, between the 23rd and 24th parallels of latitude, and longitude 86° and 87°.† Dr. Adam mentions that of Sitakhund near Monghyr on the Ganges.‡ Dr. Davy speaks of one at Cannina, Ceylon;§ and I am informed they are to be met with in Canara. Mr. Crow, formerly commercial agent of the Bombay Government in Sind, in his manuscript reports, mentions a thermal spring near Corachee on the Indus, of which the water is almost boiling hot. In Major Cruickshank's manuscript revenue map of part of Goojrat a hot spring is placed at Tooee, near Ruttenpoor on the Mhye river, in latitude north 22° 49′, and longitude east 73° 30′; and there is another at Lawsoondra, eighteen miles west-north-west of Tooee. These instances, which I am satisfied could be multiplied by diligent inquiry, afford ample proof of the wide occurrence in the peninsula of India of those singular phænomena, the satisfactory explanation of the causes of which is still a desideratum in geology.

Craters.

Volcanic products were not seen by me, nor any conformation of the hills that might be deemed an extinct crater; although the porcelain and ferruginous clays, and the exterior coat of the various quartz and jasper minerals indicate their having been exposed to igneous action.

* Gleanings of Science, vol. i. p. 36.

† Ibid, May 1831, p. 135.

‡ Geol. Trans. 1st Series, vol. v. p. 349.

§ Ibid, p. 313.

Captain Dangerfield did not meet with volcanic matters or craters in Malwa or the Vindhya range, but states a tradition exists of the celebrated city of Oogein, and eighty other places having been destroyed at a remote period by a shower of earth; and the people say that in the Vindhya range and Rajpeeply hills there are hollows near their summits "sometimes filled with water, which may be craters."* As the old city of Oogein stood upon a river constantly overflowing its banks, it was probably buried in alluvium. Mr. W. Hunter attributed its destruction to one of three causes,—earthquake, overflowing of the Seeprah, or drift earth by high winds; and, although the least probable of the three, inclines to drift earth. He states there are not any traces of volcanic agency in the buried city, nor in the neighbourhood.† The remains of the city of Mhysir, on the banks of the Nerbuddah (Nermada), are found in alluvium. We may safely say, therefore, there are not any indications of volcanic action of a comparatively recent date.

Extent of Trap Region, &c.

I will now offer a few observations on the amazing extent of the trap, laterite, nodular limestone, granite, and gneiss formations in the Peninsula, limiting their application to 25° of north latitude. My personal knowledge of the country extends from the sea on the western side to Aurungabad, in 75° 33′, and Sholapoor, 75° 53′ east longitude; north nearly to Khandeish, and south to Beejapoor and the Kristna river. Captain Dangerfield takes up the country on the north, nearly where my knowledge of it terminates, and says, "It (Malwa, including the Vindhya range) appears to constitute the northern termination of a very extensive secondary trap formation, which extends from the extremity of the Dukhun, and probably even Mysore, forming all the country above the Ghàts, and part of the plains below, on the western side of the Peninsula, including the islands of Bombay, Salsette, Elephanta, &c."‡ He carries the continuous trap north to Neemutch, in latitude 24° 27′, at 1,476 feet above the sea. Its western limit is at Dohud, longitude 74°. Major Franklin and Captain Coulthard take it up in the eastern limits of Malwa, and trace it through Sagar; and it continues to an unknown extent towards Sohagpoor and the source of the Nerbuddah river, on the table-land of Amarakantah, in longitude 82° east. Dr. Voysey describes its eastern limits at Nagpoor, latitude 21° 10′ N., and longitude 79° 14′ E., at 1,000 feet above the sea. Mr. Calder states it passes from Nagpoor southward by the confines of Hyderabad, as low as the 15th degree of latitude, and taking a north-west direction terminates on

* Malcolm's Central India, Appendix, p. 325.

† Asiatic Researches, vol. vi. p. 39.

‡ Malcolm's Central India, Appendix, p. 320.

the sea-coast at Bancoot or Fort Victoria, in latitude 18°. But specimens of rock shown to me from the Kolapoor country above the Ghàts, between the parallels of latitude 16° and 17° N., bear testimony to the trap extending nearly a degree and a half further south along the Ghàts than Mr. Calder supposed. Indeed its southern limit in the Konkun, Mr. Fraser states to be at Malwan, fifty miles north of Goa.* From the above evidence we have proofs of a continuous trap formation covering an area of from 200,000 to 250,000 square miles, a phænomenon unexampled in any other country whose geological structure has been examined. It appears to me, however, that the above are not the absolute limits of the trap. Dr. Buchanan† and Mr. Jones‡ describe the Rajmahl hills in latitude 25° and longitude 88° to 89° E. as trap; the latter says the basalt is of amazing thickness. The Rev. Mr. Everest,§ in a journey from Calcutta to Ghazipoor, passed four distinct broad beds of trap between the parallels of north latitude 23° and 24°, and longitude 84° and 87°. He states these beds to have an inclination to a common axis, and he thinks it probable they are connected beneath the granite and gneiss. Mr. Royle, travelling the same route, observed the same beds. Mr. Everest's diagram shows their longitudinal axis on a line between the Rajmahl hills and the sources of the Nerbuddah and Soan rivers; and as the trap of the Vindhya range and Sagar extends towards these sources, it is very probable the ramifications are connected with the beds (seen by Mr. Everest) and the Rajmahl hills, forming a belt across India from the 73° to the 89° of longitude, extending, in fact, from near the mouth of the Nerbuddah river to the Ganges at Rajmahl. The southern limit of trap is much lower than is assigned to it by Mr. Calder, as Dr. Voysey describes a basaltic dike at Seringapatam, in latitude 12° 26′; and Mr. Calder himself mentions partial deposits of overlying rocks as far south as Cotallum, at the extremity of the great western range, between the parallels of latitude 8° and 9°. Mr. Babington, passing through Mysore, describes all the black rocks he met with as hornblende passing into basalt. He evidently adverts also to nodular basalt.||

Age of Trap.

With respect to the age of the great trap formation of India, it would appear from Major Franklin's Memoir on Bundelkund, that its northern extremities rest on sandstone, which he considers identical with the new red sandstone of England; the trap would therefore be posterior to the carboniferous series and belong to the supermedial order. But the Rev. Mr. Everest¶ adduces valid reasons for questioning the correctness of

* Geol. Trans. 2nd Series, part i. p. 153.
† Gleanings of Science, vol. iii. Jan. 1831, p. 1.
‡ Phys. Class, As. Researches, p. 165.
§ Gleanings of Science, vol. iii. p. 135.
|| Geol. Trans. 1st Series, vol. v. p. 325.
¶ Gleanings of Science, vol. iii. p. 211.

Major Franklin's opinion; and it may be inferred that he is doubtful with respect to the exact equivalent in Europe of the Indian sandstone, as it is much associated with the primitive rocks.* In fact, where are the oolitic rocks above, and the magnesian below the red sand? where the rock salt and gypsum? and where, above all, the characteristic organic remains of the lias and magnesian limestone? It would be idle, therefore, to speculate on the era of a formation without a standard of comparison to direct the judgment. The question of the manner of the formation of the horizontal beds of trap with their vertical edges is very interesting. It will be said they were ejected under the pressure of an incumbent ocean. If such had been the case, where are the marine remains? and would not there have been sedimentary deposits upon them? Moveover, if viewed as coulées from craters, would not the beds have thinned out, instead of preserving the parallelism of their superior and inferior planes and their vertical edges?

Laterite.

Laterite is a ferruginous clay mottled red and yellowish. When first dug from its bed, it is soft and is easily fashioned into the form of bricks or large square masses for buildings, and, if my recollection serves me right, it constitutes the material of the walls of the fort at Tellicherry and the jail at Calicut. It rapidly indurates on exposure to the atmosphere. It is destitute of fossils, as far as is yet known.

That curious and very extensive rock, aptly denominated laterite (I learn from the information of a friend), occurs at the source of the Kristna river in latitude 17° 59′, at an elevation of 4,500 feet above the sea. It covers the low land between the sea and the great western range from the southern Konkun to Cape Comorin, and, agreeably to Dr. Davy, passes into Ceylon. I casually observed it at Tellicherry and Calicut, respectively 744 and 756 miles south of Bombay; and at Calicut granite rises through it. On the low land at the base of the great *eastern* range, Mr. Calder says it reappears between the 11° and 12° parallels of latitude, and recurs in increasing patches passing northwards, covering granite. The Rev. Mr. Everest speaks of laterite forming a fringe to great part of the Bay of Bengal, and covering the edge of the granite of either Peninsula.†

Nodular Limestone.

In addition to the evidence already adduced of the extensive occurrence of nodular limestone, Dr. Buchanan mentions having met with it in the Rajmahl trap hills, in Bengal and in Mysore. A writer in the

* Gleanings of Science, vol. iii. p. 213. † Ibid, vol. iii. p. 135.

"Gleanings of Science"* states that it occurred in repeated borings for water in Calcutta, at from 50 to 122 feet below the surface. Another writer† says, it is "very extensively distributed throughout Hindoostan," and further asserts that it is a "most distinguished feature of Indian geology." The Rev. Mr. Everest and Mr. Royle remarked it in their journey before adverted to. The few organic remains hitherto found imbedded belong to living speeies. The following is the analysis of "Kankar"‡ (nodular limestone) by Mr. Prinsep§:—

Water of absorption	1·4
Carbonate of lime	72·0
Carbonate of magnesia	0·4
Silex	15·2
Alumine and oxide of iron	11·0
	100·0

Kunkur, or nodular limestone, has been likened to the cornbrash of the English strata; but its geological position (prineipally superfieial), and the absenee of charaeteristic fossils, present insuperable objections to their identity.

Granite.

The late Dr. Voysey states, that he "had reason to believe, partly from personal observation and partly from speeimens obtained from other sources, that the basis of the whole peninsula of India is granite; he had traced it along the coast of Coromandel, lying under iron clay (laterite); also in the bed of the Godavery river, from Rajamahendri to Nandair; and he had specimens from the base of the Sitabaldi hills of Nagpoor, from Travankur, Tinnevelli, Salem, and Bellari." Mr. Stirling, in his memoir on Cuttaek, says, "The granite where my specimens were prineipally eolleeted appears to burst through an immense bed of laterite (iron clay) rising abruptly at a eonsiderable angle."‖ Major Franklin adds to the above quotation, "The plains of Bundelkhund attest that granite is there the basis rock." Ceylon is exclusively granite and gneiss; finally, I observed granite rising through laterite at Calieut on the Malabar eoast. With these faets before us, we ean searecly question the truth of Dr. Voysey's opinion; an opinion involving the belief, with referenee also to the extent of trap, that the whole peninsula of India and Ceylon, eovering an area roughly calculated of 700,000 square miles, is of igneous origin.

* Gleanings of Science, vol. i. p. 169.

† Ibid, vol. i. p. 365.

‡ Properly *Kunkur.*

§ Gleanings of Science, vol. i. p. 278.

‖ Physical Class, Asiatic Researches, p. 37.

Sedimentary Rocks.

I am not aware of the existence of any sedimentary rocks in Western India, south of Baroach, excepting such as have probably originated in the consolidation of comparatively recent alluvium.

Recapitulation.

I close this paper with a recapitulation of the characteristic geological features of the Peninsula; namely, the amazing extent of the trap region, and the horizontal position of its stratified beds; the granitic basis of the whole country; trap veins in granite; the absence, as far as is known, of that uniform series of rocks which constitutes the formations of Europe; the extended and peculiar nodular limestone and laterite formations; the occurrence of pulverulent limestone in seams; and finally, the non-discovery hitherto of the fossil remains of extinct animals within the limits of the Peninsula.

London, January 21*st*, 1833.

A few words are necessary in explanation of the sections which accompany this paper. They represent two principal spurs from the Ghàts, and converge to the same point at the junction of the Goreh and Beema rivers. In strictness they are not sections, ramifications of the spurs, and hills at short distances north and south of the central vertical plane being inserted: they partake, therefore, of a slightly perspective character, but this does not affect the general correctness of their geological features. Fig. 1 comprises the range of hills between the Under and Beema rivers, and has a length of about seventy-five miles. Fig. 2 shows the mountains between the Bore Ghàt and the source of the Mota river, and extends nearly eighty miles. The length and elevation are expressed by different scales, and from this cause the outlines of the mountains are not rigidly correct. A bare outline is traced from the Ghàts westward to the sea, for the purpose of showing the curious forms of the weathered basaltic caps and ridges of the mountains in the Konkun.

The elevations were determined either barometrically, or thermometrically. Those marked "B" are barometrical, and result from simultaneous observations with previously-compared barometers, all the necessary corrections having been applied for temperature, moisture, and latitude. Those marked "W" were obtained by ascertaining the boiling-point of water at different elevations with delicate thermometers:

they are not to be relied upon within 100 feet, although in some instances, when tested by barometrical measurements, they corresponded within a few feet.

Of the Panoramic Sketches, Plate IV. No. 1 is a distant view of the mountains on which are situated the celebrated hill forts of Jewdun, Hurreechundurghur, Koonjurghur, and Sewneir, in which Sewajee, the founder of the Mahratta empire, was born. It is taken from the hill N. of the town of Goreh.

No. 2 is a view of the hills, to the north and east, as seen from Lakungaon in the flat broad valley of Jooneir (Sewneir).

No. 2* is a continuation of the view No. 2, from the N. round to the west.

No. 3, a sketch of the hills, to the north and east, as seen from the summit of the armoury, in the fort of Ahmednuggur.

No. 4 is a sketch of the northern flank of the plateau on which the city of Ahmednuggur stands, as seen from Wamooree, in the plain of the Godavery river.

MAP AND PLATES

To illustrate Colonel Sykes's memoirs "On a portion of the Dukhun in the East Indies."

Map of the *Dukhun.*

PLATE IV.

Panoramic Sketches.

No. 1 is a distant *view of the mountains* on which are situated the celebrated *hill forts of Jewdun,* &c. It is taken from the hill N. of the town of *Goreh :* p. 114.

No. 2, a view of the hills, to the north and east, as seen from Lakungaon in the flat broad valley of *Jooneir* (Sewneir).

No. 2* is a continuation of the view No. 2 from the north round to the west.

No. 3, a sketch of the *hills to the north and east,* as seen from the summit of the armoury, in the fort of *Ahmednuggur.*

No. 4, a sketch of the northern flank of *the plateau* on which the city of *Ahmednuggur* stands, as seen from *Wamooree,* in the plain of the Godavery river.

PLATE V.

Fig. 1, elevation and declination of the *country above the Ghàts,* between 73° 35′ and 74° 49′ east longitude, and 18° 50′ and 19° 10′ 3″ north latitude: p. 91—98, 114.

Fig. 2 † elevation and declination of the *country above the Ghàts,* between 17° 35′ and 74° 49′ east longitude, and 18° 28′ and 18° 50′ north latitude: p. 105—114.

These Sections are fully explained above.

† In the engraving of fig. 2, the names *Moteh* and *Mota* are confounded. *Mota* is the name of the river, *Moteh* that of the town.

Geology of the Island of Bombay. By H. J. Carter, Esq., Assistant Surgeon, H. C. S., Bombay.*

[With a Geological Map and five Plates.]

Read December 1850.

Difficult as it may appear to unravel the geological history of a tract of country which has been overflowed and ploughed up by successive volcanic effusions, and subsequently elevated, depressed, immersed, or denuded, or all four put together, yet, by patient investigation and search, such a knowledge of its structure and composition may be obtained, as to enable the observer to bring back, in his imagination, to their original state and position, the materials of which it was originally composed, and to place before the reader a satisfactory account of the changes which it has undergone during a given geological period,—changes which to him would otherwise be incomprehensible.

The little island of Bombay, just peeping above the waters of a muddy estuary, would seem to offer little or no novelty in this respect, particularly when compared with the great mountainous masses which surround it; but, when observed carefully, it will be found that what it lacks in size is compensated by amount of excavation, and that the latter has in all probability disclosed the geological type of the whole neighbourhood in its limited space.

Was the island of Bombay, as at first sight appears, composed of one mass of the same kind of dark-looking trappean rock, its geology might be told almost in as many words; but when it is found to present in its thickness the strata of an ancient lake, or river; a coal-deposit in miniature, filled with the fossillised *débris* of animal and vegetable remains, some, if not most, belonging to species now wholly extinct; and that there have been three or four successive effusions of volcanic matter over and into these strata, forming ten times as many different rocks, it naturally suggests the questions—How far did this lake extend? Was it a lake, or a river, or an estuary? On what kind of rock were its strata deposited? Of what material are its strata composed? To what extent does its coal-deposit extend? What was its geological age? When was it

* Reprinted with slight alterations from the Journal of the Bombay Branch of the Royal Asiatic Society, vol. iv. p. 161.—July 1852.

destroyed and filled up? What rock first covered it? What kind of rocks subsequently forced their way into it? Has the island undergone any elevation or depression, and have any other strata been deposited on it since the period of active volcanic action ceased? Does the nature of its volcanic effusions, or their relative positions, bear any analogy to similar effusions in the adjoining islands, and on the mainland itself?—are all questions which make the little island of Bombay assume a geological importance as interesting as at first it appeared to be unpromising. Let us now see if any of them can be answered.

From the following facts and observations it will be evident that there have been four distinct periods in the formation of the island of Bombay, viz. 1*st*, that of the primary volcanic or trappean effusions; 2*nd*, that of the deposit of fresh-water strata; 3*rd*, that of the secondary or subsequent volcanic effusions; and 4*th*, the deposit of the marine strata.

1st Period.—With the rocks of this period we have little or nothing to do, as they form no part, so far as my observations extend, of the island of Bombay; but as the island must be based on something, and there is nothing else in the neighbouring country and islands but these primary effusions intruded and overlain by the secondary ones, we may confidently assume that they form the basis of the island of Bombay, and that the fresh-water strata were deposited on the last of them.

2nd Period.—Of the fresh-water formation, which is next in age, we are unable to come to any conclusions beyond the following, viz. that by the absence of marine fossils in it, and the presence of fresh-water ones, it was deposited in a lake or river; that its upper part is seen entire for 36 feet below the igneous rock which overlies it; and that below this again its strata have been intruded and broken up by other igneous rocks; so that, at present, we can neither tell its whole thickness, nor do more than assume, as before stated, that the rock on which it was deposited is trappean. As to its limits horizontally, it can only be at present stated that it extended all over the island of Bombay, and that portions of it may be seen in the volcanic breccia at Ghora Bunder, a little village on the northern extremity of the island of Salsette, thus giving it an extent north and south of at least twenty miles. We shall see also, by the presence of organic remains in this formation, that it must have been the depository of a large quantity of wood, leaves, fruits, &c., and that these are generally in a fragmental state, and jumbled together, as if they had been brought from a distance; also that plants, having conical bulbous roots, with stems formed of concentric layers, as if made up of sheathing leaves, like large bulrushes, grew in this lake; that it swarmed with the little

entomostraco-crustacean animals called *cypridæ*, and that an abundance of small frogs and marsh-tortoises were also present. Moreover, that the material of which its strata are composed seems from its colour and composition to be of volcanic origin, but deposited for the most part in a subtle state, though occasionally granular and coarse-grained, but never gravelly or quartzy—always argillaceous. This, from the thin layers of which the formation is composed, must have subsided very gently, and would therefore come nearer to the sediments of a lake than those of a swift stream. At what geological period they were formed is not yet known, because there have been no fossils yet found in them which can determine this; but a time arrived when the volcanic material in which they are presumed to have originated was no longer transported through the agency of water, but came in a molten fluid, and, filling up the lake, dried up or turned off its waters, and changed the then sub-lacustrine plain of Bombay into one of dry black igneous rock. This was the first of the secondary or subsequent volcanic effusions.

It is most probable that the lake was above the level of the sea at the time this occurred, although the general level of its strata is now below it. One other fact connected with the fresh-water formation is here worth mentioning, viz. that within three inches of the igneous rock which overlies it, there is a stratum three inches in thickness, almost entirely composed of the casts of *cypridæ*,—not of their valves singly, which they are wont to shed annually, but their entire casts, showing that some sudden alteration of the water in which they were living took place, by which they all as suddenly perished and fell to the bottom. After this occurrence no organic remains are seen, and nothing but the three inches mentioned, of a kind of transitional material between the fresh-water formation and the basalt. The amount of coal in this formation will be seen to be very trifling, and that nearly the whole of the wood and other vegetable remains have been replaced by argillaceous material. At the same time, it will also be seen that it is only at one place that the highly carboniferous part has been exposed, and that, too, over an area only of a few square yards, viz. in the cutting for the sluices, where the main drain of the island empties itself into the sea.

3rd Period.—This commences with the 1st of the secondary effusions or *Trappito-basaltic* tract, which caps the main ridges in Bombay, and which, it may be presumed, was once continuous all over the island. How far it extended beyond this, it is not our present object to inquire; it is enough for us to know that it overflowed the then plain of Bombay. Originally it was probably much thicker than it is at present, but the weathering of ages has of course much reduced it, though even now it may be seen to measure 90 feet thick on the eastern, and 51 or more on the western side of the island. Immediately after this effusion, we may

conceive the site of Bombay to have been part of a black arid plain: how long this continued geologically we have no proofs to show, but after it had become hard, probably, and fixed, there was a 2nd-effusion, which, coming up under the first and not finding a ready outlet, followed the course of the fresh-water strata below it, intercalating them, and breaking them up into all-sized fragments. This effusion was for the most part scoriaceous or cellular, and gave rise to the amygdaloidal structure which is now its chief characteristic; though in Nowrojee Hill quarry it is compact, which might have arisen from the superincumbent weight of *Trappite* over it at this part. The amygdaloid rock is found invading the fresh-water strata in every part of the island, in one form or another, non-cellular or cellular; the cavities in the latter instance being filled with laumonite, green-earth, quartz or calc-spar, according to the locality. The part which this effusion took in raising up the longitudinal ridges, in the plain of the first effusion, and which ridges, running about N. by E. and S. by W., now border the eastern and western sides of the island, there is no evidence to show; but that this, or the 3rd-effusion, to which we now come, or both, were active agents in this matter, there seems to be no reason to doubt, for we find those parts of the ridges most elevated where these effusions are thickest, and in the western ridge either one or the other is seen filling up the internal angle of the roof-like elevation formed by the fresh-water strata there. We have, then, a *Trappito-basaltic* effusion, and an amygdaloidal effusion; and now we arrive at another effusion, which we shall term the volcanic breccia. How long an interval elapsed between the amygdaloidal effusion and that which gave rise to the volcanic breccia is as inconceivable as the duration of the interval which existed between the first and second effusions, there being nothing in the island of Bombay to give the slightest idea of either; but, that the volcanic breccia was formed subsequently to the amygdaloid, is proved by the presence of fragments of the latter among the fragments of the other rocks which form the heterogeneous compound of the former. The principal characters of this effusion are, that it is composed chiefly of angular fragments of the fresh-water formation, varying in size from particles which are invisible to the naked eye to pieces some tons in weight; also, that it contains fragments of various sizes of the two foregoing effusions; and, lastly, that it is of great extent,—forming a continuous tract from Carnac Bunder all along the eastern shore of the island to Sion, and here composing the plain and chain of hills which bound the north-eastern part of the island; also, still more, viz. the principal part of the mountains in the island of Salsette. It is this effusion which I think contemporaneous with the lateritic formations, and in some parts identical with them in every respect; but this will be better understood by a reference to the latter part of the detailed descrip-

tion of this effusion,—we are chiefly concerned with it here as an agent in the changes of form which the first plain of volcanic rock has undergone; and no one can witness the cropping out of this breccia all along the base of the highest parts of the eastern ridge, and its free effusion at the north-east part of the island, with wells extending into it 60 feet deep in Mazagon, and veins and dikes of it bursting through the *Trappito-basaltic* tract in the same neighbourhood, without feeling satisfied that, to make room for such an immense mass, the crusts of the previous rocks must have given way, and have been forced ridge-like upwards, as we now see them; to give vent to the volcanic torrent, which, breaking through the fresh-water formation and igneous rocks that opposed its progress, finally spread their fragments, in the manner we have seen them, along the eastern shore of the island.

The protean forms assumed by this effusion and its decompositions, passing through so many different rocks, may easily be conceived; it is therefore white at one part, blue at another, yellow at a third, brown at a fourth, red at a fifth, and black at a sixth, with all the intermediate shades; composed, as before stated, of fragments of rocks in the immediate vicinity, changed into all degrees of consistence, and, more than that indeed, fragments of large-grained *diorite*, which have come up from a region much below any we are acquainted with in Bombay. As to structure and hardness, it presents every stage, from the coarsest and softest argillaceous breccia, which may be cut with a knife, to the blackest and hardest homogeneous jasper, seen at the hills of Antop and Sewree. Such a destructive agent, then, as this effusion must have been, might be safely allowed to have been the one most active in the upheaval of the longitudinal ridges in the island of Bombay, and of the *trappite* ones at least, in the island of Salsette.* Lastly, we have a 4th-effusion, and this is proved by the existence of dikes of volcanic breccia through the last mentioned. Of their contents, little can be made out, and they prove nothing further than that the third was not the last effusion. In the detailed descriptions of the three latter effusions, I may have mentioned some little tracts as pertaining to one which may pertain to another; but it is almost impossible to expect accuracy in this respect with effusions which are all more or less alike, and errors of such kind, after all, are of little importance, as they cannot affect the general conclusions, and, moreover, the observer may correct them as he best likes, himself. That there have been four successive effusions in the secondary volcanic period, there can be no doubt; and that the three latter, pursuing a course in the first instance under the *Trappito-basaltic*

* The culminating mountain in the island of Salsette, which is 1,551 feet above the level of the sea, is, together with the ridges flowing from it, chiefly composed of this volcanic breccia.

tract, have all contributed to destroy its horizontality, by raising up the ridges which now exist upon it, is equally obvious. With the dikes, which have been last mentioned, the period of active volcanic action in the island of Bombay seems to have ended ; how far passively the island has since been affected there is nothing to determine.

4TH PERIOD.—*Deposit of the Marine Formation.*—There is nothing in this to make us think that it is of very ancient date geologically : it would seem to belong to the post and newer pliocene formations. The clay and lower part of the beach, as no remains of human bones or artificial structures have I think been found in either, perhaps belong to the former, while the shells consist of the same species as those which are found on the shore at the present time. That the island has undergone elevation since the period of volcanic action ceased would seem to be proved by the remains of a portion of sea-beach called "Phipps' Oart"* in the centre of the island, near which no sea now comes ; but the elevation must be very trifling, for the ridge of a beach is always higher than the sea, even at the highest tides, and the summit of this is only eight or nine feet above high-water mark ; while the accumulation of detritus poured into the estuary of Bombay from the neighbouring hills is as likely to have produced it, after having filled up the lagoonal depression in the centre of the island to the level of the sea, as anything else.

At the same time, Bombay could never have been very deep, or long under water, or the deposits on it would have been much thicker than they are, and of more ancient date ; as it is, the beaches hardly exceed 20, and the clay 10 feet in thickness. Where there is no clay, as close to the shore, the beaches are thickest, and *vice versâ.*

The resemblance which the *Trappito-basaltic* tract and amygdaloidal effusions bear to those on the mainland is most striking, and may be seen by a reference to Colonel Sykes' valuable paper on the Trappean Region of the Dekkan and Konkan immediately opposite,†—that of the adjoining islands I hope at some future period to show myself.

Such is a short summary of the geology of the island of Bombay, and I have premised instead of appended it, in hopes that the reader may be induced to peruse the following descriptions in detail from which these inferences have been deduced ; let us begin with a brief outline of its geography.

The island of Bombay is trapezoidal in figure, having its long axis nearly N. by E., and S. by W., its short parallel side towards the sea, and its long one towards the land. The outer side is six miles long, and the inner one eleven miles ; both are bordered by ridges of hills, precipitous towards the east, while they slope gradually towards the west.

* This has all been removed now for the railroad.

† This volume, p. 39.

Between these ridges, which are about two miles apart, there is a level plain called the "Flats." The greatest width of the island is a little more than three miles.

At the two short sides of the figure there are sandy beaches, which, being above the level of the "Flats," prevent the sea from overflowing them, but on the outer side of the island there is no beach, because the whole is black *basalt*, probably extending a long distance into the sea; while on the inner side, which borders the harbour, there is an accumulation of silt, deposited from the back-waters and the rivers which empty themselves into the estuary in which the island of Bombay is situated.

The southern extremity of the outer side of the island is called Malabar Point, and the northern Worlee; while the southern extremity of the inner side is marked by the Light House, which stands on the extreme end of a thin prolongation named Colaba; and at the northern extremity is a tower called Riva Fort. Between Malabar Hill and the extremity of Colaba is a deep bay, called Back Bay, in which there is a sandy beach, and on the opposite or corresponding side of the trapezoid is a similar excavation, in which there is also a beach, called Mahim Sands. Both of these beaches are a few feet above high-water mark, and they chiefly prevent the sea from overflowing the centre of the island.

The highest point in the lateral ridges (which are interrupted more or less by breaks here and there) does not exceed 180 feet, which is the height of Malabar Hill just above the eastern corner of Back Bay. The southern part of the eastern ridge, called Nowrojee Hill, is 117 feet; Mazagon Hill, next to it, 162 feet; Chinchpoogly Hill, 153 feet; Parell Flagstaff or Colongee Hill, 163 feet above high-water mark; and Antop Hill, which is in the centre of the little range bordering the north-eastern part of the island, is 85 feet; while another hill in the same range, a little to the north of it, is about 127 feet above high-water mark,—the latter has been measured by comparison.

The "Flats" are but just above the level of the sea, which overflows a small portion of them at the "springs," and the ridges of the beaches average about six feet above high-water mark.

From this description it must be evident that a section of the island of Bombay, either longitudinally or transversely, if proportionally given, will have a very insignificant appearance. (See Map, fig. 2.)

With respect to its relations with the mainland, Bombay is separated to the northward from the mountainous island of Salsette, which is six or seven times larger, by a channel narrowing to a part not more than 125 yards wide; while Salsette, again, in like manner, is separated from the mainland by a similar channel. To the south and east of Bombay is its harbour, in which are also several mountainous islands and islets, that lie scattered between it and the mainland. The harbour or estuary is about six miles across in its widest part.

This short geographical introduction will be sufficient to explain the map of the island of Bombay hereto annexed; let us now proceed to its geology.

Insignificant as the elevation of Bombay is from its low hills and general flatness, yet it is by no means so in geological composition, for although its structure is not known for more than 60 feet here and there below high-water mark, which, added to its highest point, gives only a total thickness of 240 feet, yet in this thickness we have from 30 to 50 feet or more of fresh-water strata, covered by volcanic rock, which has been thrown out over them, in some parts 90 feet thick, and pierced by various subsequent effusions even still thicker; together with a marine formation, filling up the lagoonal depression of the island, and consisting of mud, in some parts 10 feet, and in other parts sandy beaches, 20 feet thick. Thus we have abundance in a geological point of view to occupy our attention, although we have little geographically.

But, before proceeding further, it would be as well to consider the general composition of the ridges of the island, as well as the mineralogical characters in detail of the masses which compose them, in order that we may arrive at a right understanding of the relative position of the latter, and the names by which we intend to designate their various forms.

The rocks of Bombay, which chiefly form its ridges, come under the class volcanic, and all belong to the trappean system: there are no hypogene rocks, that is, igneous rocks which have been formed below the surface, and afterwards raised above it. Besides these, there is a series of aqueous strata, which comes under the head of fresh-water formations, from the character of its fossils; and this, as before stated, is overlaid and intruded by both the volcanic rocks.

The whole of the upper part of the eastern ridge, from Riva Fort to the end of Colaba, is composed of fine-grained *Trappite*, more or less basaltic towards the summit, while the whole of the upper part of the outer or western ridge is composed of fine compact black *Basalt*. Both of these rocks rest conformably on the fresh-water formation, which is composed of argillaceous and bituminous shale, broken up by subsequent volcanic effusions, assuming the forms of aphanite, spilite, amygdaloid, &c. which, as will hereafter be seen, are only modifications of *Trappite*.

Such is a brief outline of the general composition of the ridges, and the relative position of the rocks which compose them; the following are the mineralogical characters of the latter. I should here premise, also, that in nomenclature I shall chiefly follow M. Alexandre Brongniart's classification and mineral characters of rocks, as given under the article "*Roches*," in the Dictionnaire des Sciences Naturelles.

Trappite, Bgt. (*synonys.* whin-stone, greenstone, diorite) is chiefly

composed of crystalline felspar and hornblende, together with a little amorphous argillaceous earth. It is either coarse or fine-grained; that of Bombay is chiefly fine-grained, and its structure hardly perceptible to the naked eye; but on being magnified, the dark green hornblende becomes easily recognisable as well as the less coloured felspar, and the amorphous earth between them. When it is very compact, hard, sparkling, and sub-granular, its ternary compound and crystallisation almost undistinguishable, and its homogeneity almost complete, then we shall call it "*Basalt*"; and in this state, presenting a blue-black or black-purple colour, it forms the upper part of the western ridge, while *Trappite*, passing into a basaltic form, in its upper part forms the eastern ridge. When *Trappite* loses its crystallisation entirely, it becomes *aphanite* (Bgt.), from ἀφανίζω, "to make unseen," in allusion to the felspar. I shall not use the term "Trapp" as a specific appellation here, as it confuses, and *Trappite* and *aphanite* will, I think, be found sufficient. In this way, then, the distinguishable ternary compound of *Trappite* may pass into the undistinguishable compact one of *Basalt* on the one side, and into the earthy one of *aphanite* on the other. Now when *Trappite* and *Basalt* are cellular, and their cavities are filled with green earth, zeolites, quartz, amethyst, calcedony, or felspar, they are termed amygdaloidal or variolitic; while *aphanite*, when cellular and similarly charged with these minerals, more especially calc-spar, has been called "*spilite*" (Bgt.); but all three are substantively called "*amygdaloid.*" Under the foregoing names, then, the principal of the trappean rocks in Bombay may be included.*

* M. Brongniart's definition of "trappite" is thus given:—

"TRAPPITE (Roches de Trapp).

"Base d'Aphanite, dure, compacte ou sublamellaire, souvent fragmentaire, enveloppant du Felspath, de l'Amphibole, du Mica.

"*Parties accessoires.*—Titane nigrine, Augite, Pyrite, Grenats."

Thus, with the exception of the Mica, this definition is applicable, in the way above stated, to the greater part of the Trapp (using the name generically) that I have seen in Western India. But *Trappite* should not be confounded with *Diorite*, as I have frequently found it done here. That there is no line of distinction between some few portions of the Trapp and *Diorite* may be easily conceived, viz. when the earthy ingredient becomes so scanty in the *Trappite* as not to be appreciable, and this ingredient, thus disappearing, leaves nothing but the crystalline felspar and hornblende behind, which is essentially the composition of *Diorite*. But this is the exception and not the rule; and as it is desirable not to confound rocks of different ages, it is also desirable not to use names which may tend to this, as the application of *Diorite* to any parts of the great trappean district of Western India. Hence it would be better always to use the word "*Trappite*" where even the rock may appear as crystalline as *Diorite*, for if the two were compared together it may, I think, be fairly presumed that a genuine specimen of *Diorite* could never be confounded with any portions of the great trappean effusions of Western India. The feature, then, which chiefly distinguishes *Trappite* from *Diorite* is the amorphous earth, the former is a ternary, semi-crystalline, therefore, and the latter a binary, crystalline, compound. It only requires to see the prevalence of *Diorite*, Bgt. together with *Ophiolite*, Bgt. (Serpentine)

We next come to the fresh-water formation, in which we have argillaceous shale, argillo-calcareous shale, and argillo-bituminous shale, with small quantities of coal; also chert and jasper, arising from the exposure of the argillaceous strata to great heat.

Add to the foregoing a volcanic breccia, composed of fragments of the other formations, bound together by a base of *aphanite*, more or less fine, more or less coarse; harder or softer, and sometimes passing into a black jasper, as at Sewree, and Antop Hill.

Lastly, we have the blue and brown clay of the "Flats," containing the calcareous concretions called *kunkur;* and the consolidated sand and sea-shells of the beaches.

Having thus premised sufficient to prevent a misunderstanding in the terms which will be used, and the kind of rocks they designate, let us now trace the different formations mentioned throughout the island, beginning with *Trappite*, which is the most prevalent, the most prominent, and the most widely-spread of all.

Trappite.—This rock forms the summit of all the eastern ridges, except that bordering the northern part of this side of the island, and will be found to extend continuously from the extremity of Colaba to Riva Fort, that is throughout its whole length. It is interrupted by breaks or breaches here and there, and diminishes in height towards both extremities; but between the "Fort" and the village of Nagaum, a distance of five miles, it presents points of variable heights, rising to 163 feet above the level of high-water mark. In some of the breaks it appears to be so expended that its continuity is hardly traceable, as at Nagaum, while in other places, as at Nowrojee Hill, where it has been quarried, it is 90 feet thick. Again, the width of this tract varies, so far as it is observed superficially: it forms the whole of Colaba, and the eastern part of the Esplanade and Fort, and, of course, it extends into the harbour on one side, and, obscured by the beach which forms the Esplanade, appears in Back Bay again on the other; but at present it will only confuse us to trace it where it is concealed, and, therefore, we will confine our observations to where it is exposed. It forms also the eastern part of the Native Town, at the northern extremity of which is

on the coast of Arabia, and the Trapp rocks among it, to become sensible of the desirableness of not calling any of the latter *Diorite;* and the same probably applies to India.

Applicable, however, as the above composition of *Trappite* is to most of the Trapp of Western India, the specific distinctions given by M. Brongniart to his "*Basanite*" are no less applicable; but, as he states at the end of his remarks on *Trappite*, "Le nom de Trapp a été appliqué à tant des roches homogènes différentes, qu'on ne peut donner comme examples certains que ceux qu'on a eu occasion d'observer soi-même."

When the first edition of this paper was published I used the word "*Diorite*" where I have now used *Trappite*, but I was not then aware of the distinction to which I have above alluded, or the necessity of not confounding the Trapp, with the *Diorite* of Western India.

the quarry of Nowrojee Hill, where, as before stated, it is seen to be 90 feet thick; here, also, its superficial area is greatly expanded, and extends continuously across the island from Mazagon Hill due west to the "Flats," a distance of one mile. This breadth is greater than at any other part, and is prolonged from Nowrojee Hill due north to the Mount, a distance of one mile and a quarter. At this part, also, it has been intersected and pierced in all directions by a subsequent effusion, which we shall come to hereafter. At the Mount it narrows again, and spreads out on Chinchpoogly Hill, and thence is continued on over Colongee or Parell Flagstaff Hill to the village of Nagaum; here it sinks to within a few feet of the level of the "Flats," and appears only in the form of a few boulders for half a mile, when, rising again a few feet more or less, it at length reaches Riva Fort, the northern extremity of the island. The principal feature of this ridge is, that it is more or less precipitous towards the east, while it slopes more or less suddenly towards the west; a character which, it should be remembered, is common to every hill in Bombay, without exception. Its summits and sides are also covered with naked rocks and boulders, from the mode of desintegration of the *Trappite* which follows the veins with which it is intersected; hence they are in cuboidal or polyhedral masses, and, when more minutely divided, end in becoming spheroids, throwing off concentric crusts.

The mineralogical composition and structure of this rock vary. Generally, its crystalline structure may be distinguished with a good magnifying glass, but sometimes it becomes so minute, and compact, and tough, that it almost takes on the form of the Bombay *Basalt;* still we may infer its composition by seeking out its structure in larger-grained specimens. In these we shall find tabular crystals of white felspar, amorphous crystals of green hornblende, a small quantity of greenish or blue argillaceous earth, and more or less green-earth, olivine, and small particles of peroxide of iron,—probably titanitic iron or rutile from its rich brown-red colour in some parts,—most of which are caught up by the magnetised needle in their natural state when the mass is pulverised, but this, of course, can only be seen by manipulation under a high magnifying power. The presence of the iron accounts for the decomposition of the rock into greenish blue, then yellow, and lastly red earth, these being the usual colours which iron assumes in passing from its protoxide to its peroxidised state.

Further, it may be observed of this rock, *en masse*, that the upper part is more crystalline, tougher, and more difficult to break than the lower part, while the latter, on the contrary, is more cleavable. Cavities are sparsely scattered in it, which contain varieties of scolezite or needle-stone, the latter name being derived from its spicular crystallisation. In some parts it is blacker than in others, while frequently it presents a

spotted appearance, on account of the dark portions being circumscribed instead of generally spread throughout the rock. I am unable to explain the latter appearance, except that the hornblende is blacker in these places than in others, probably from the greater quantity of protoxide of iron which it contains; in other words, that the distribution of the iron throughout the rock has been unequal, or has become aggregated in some parts of it more than in others during crystallisation, or *ab origine*. In the next ridge I am about to mention, this mottled state prevails very much, and on weathering the dark portions remain, while the lighter parts wear away, giving the surface a grape-like appearance, in which the spheroids are about the size of bullets.

This ridge is very low, scarcely rising at one or two points more than 50 feet above the sea. It lies on the east side of the latter, and commences close upon the sea opposite Mazagon Hill, from the base of which it is separated by subsequent effusions of volcanic matter. Its rocks, which appear just above the sea at the commencement at Mazagon, rise gradually to Tank Bunder, where there is a high mound of it, after which it sinks below the mud, and subsequently makes its appearance again at Kandlee Battery: there, as at Tank Bunder, it rises to about 50 feet above the sea, and again sinks gradually, as it pursues a direct line northwards to within a hundred yards of the base of Colongee or Parell Flagstaff Hill, where it ends; being separated the whole way from the first ridge by the subsequent effusion to which I have alluded. It does not differ in composition or structure from the *Trappite* of the first ridge, except that its surface in many places weathers into the grape-like structure mentioned, particularly a little south of Tank Bunder; this is its great peculiarity, and hence it might be called "*Orbicular Trappite*" in contradistinction to "*Orbicular Diorite*" (Bgt.). It is very insignificant in height, when compared with the first ridge; but is, in like manner, tilted up and precipitous towards the east.

Lastly, we have a third ridge of *Trappite* on the east side of the island, which begins at a point 400 yards NE. of Kandlee Battery, called Jackaryah's Bunder, and 600 yards east of the first ridge. It pursues a course a little to the eastward of north, and, about a mile from its commencement, attains a height of 78 feet, after which it gradually gets lower, and finally joins the first ridge about two and a half miles south of Riva Fort, or about half a mile beyond Nagaum. In mineral composition, structure, and physical features, it corresponds with the first ridge, being scarped on the eastern, and sloping more or less suddenly on the western side.

In addition to the main ridge, then, there are two other short ridges of *Trappite* on the eastern side of the island, and all these rest on the fresh-water formation, as we shall presently see; let us now go to the western side.

*Basalt of Bombay.**—The western ridge, which extends from Malabar Point to Worlee Fort, is entirely of black, or blue-black basalt, interrupted by a break or two. Its height, as before stated, in one part, exceeds that of any other hill on the island, being 180 feet above high-water mark, just over the western corner of Back Bay. Like the eastern ridge, it is scarped on the eastern side, and slopes more or less suddenly on the western one, passing off afterwards with a very slight inclination into the sea. In its broadest part it is about 600 yards wide, that is, the distance between the precipitous side and the sea, and everywhere it appears stratified, the lines of stratification dipping suddenly, in the ridged portion, towards the west. In its scarped portion it presents a columnar arrangement, consisting of large cuboidal masses, arranged one above another; while its surface in some parts presents an hexagonal prismatic arrangement, to wit on the shore at Worlee, and in Back Bay. It is fragile almost to brittleness a little beneath the surface, but superficially, where it presents the hexagonal arrangement, is exceedingly tough. Throughout it is minutely divided by intersecting quartziferous veins, the structure of which, where exposed, is open and cellular, and of a rusty colour, while the centre of the polyhedral masses which they surround is firm, black, and compact. Like the *Trappite* of the eastern ridge, it decomposes into spheroids, throwing off concentric crusts; in some parts, however, beneath the surface, it appears to undergo an irregular jointed disintegration, the surface of the fragments presenting a greenish-blue coloured argillaceous earth, which afterwards becomes brown, yellow, or red. There is a remarkable absence of cellular cavities in this rock,—I do not know that I ever saw a trace even of any except here and there, where there was a little olivine: its chief difference from the *Trappite* of the eastern ridge lies in its black colour, and in its compact structure and minute texture, which defies all attempts at analysis by optical examination; also in its apparent stratification and hexagonal prismatic arrangement on the surface in some places, and in its more rectangular disintegration. Like the *Trappite*, however, of the eastern ridges, it rests on the fresh-water strata, but is nowhere pierced, to my knowledge, by any subsequent effusion. Thus, with these little differences set aside, it so much resembles the *Trappite* of the eastern ridges that one can hardly consider it otherwise than as a more compact part of one and the same formation, which was once continuous across the "Flats," but has been since separated by fracture, upheaval, and denudation. To this effusion, therefore, we will give the name of "Trappito-basaltic Tract."

Fresh-water Formation.—Next in succession below the *Trappito-basaltic* tract comes a series of aqueous strata, which by their fossils are

* For the distinction between this and the *Basalt* of the Dekkan, see my "Summary of the Geology of India," further on.

proved to have been deposited in fresh water. They consist of argillaceous shale, which, so far as it has been exposed, appears to have been formed from the fine detritus of volcanic matter, with which is mixed a quantity of organic remains, both vegetable and animal. In their upper part they are of a light brown colour, passing gradually downwards into a greenish or bluish deposit, and then into black bituminous shale. In no part do they, to my knowledge, present any gravel or large detritus.

At their junction with the basalt, at the cut of the sluices at Lovegrove,—for we will, before tracing these strata over the island, study them at this part, where they are least disturbed and best seen,—the basalt is decomposing for some distance up, and passing into spheroids, which become more and more divided, until they disappear altogether, and leave nothing but a few traces of their concentric crusts: at this point the basalt rests upon the aqueous strata, and presents a number of vertical tubes, filled with crystalline quartz. These tubes are about five or six inches long, about half an inch broad at the base, and taper towards the extremity: some rise immediately from the surface of the aqueous strata, others a little above it. They are either solid or hollow, and occasionally bifurcated below, and were probably air-cavities in their original state, perhaps produced by the evolution of gases from the vegetable matter over whieh the fluid basalt had spread itself. These tubes are best seen on the eastern side of Lovegrove Point, under the tomb of Mama Hajanee, near high-water mark ; they exist also at the sluiees, but I have not seen them anywhere else.

Lying immediately below this is the first stratum of the aqueous deposit, which is only three inches thick, and presents nothing, apparently, but the transitional state of the voleanic into the aqueous formation. Next it, however, comes a remarkable layer, though not thieker than the foregoing, which is compact and siliceous : the peculiarity of this is that it is almost wholly composed of casts of the shells of the little entomostraceous crustacean animals called *Cyprides*, with which is mixed a variable quantity of vegetable remains, consisting of small short fragments of plants, without any particular shape. It also has another peculiarity, which is, that it is almost wholly composed of silex, in the form of amorphous or crystalline quartz, which has either wholly or partially filled the cavities of the shells, the forms of the shells themselves having disappeared. Hence we find this stratum in preference to all others ehertified, jaspidified, or blackened and basaltified by heat; and thus we have in many plaees evidence of the existence of the upper part of the fresh-water strata, where the rest have had their stratification destroyed, or have had their structure almost wholly transformed into something else. This stratum is well seen at Lovegrove Point, and on the northern side of the break in the ridge through which the

sluices have been cut. It will be recognised by its whiteness, and its oolitic structure, immediately underlying the black *Basalt*. At the northern side of the sluices it presents a remarkable fold upon itself, which, before it is understood, is very confusing, insomuch that it gives the appearance of two or three of these kinds of strata, instead of only one.

From this deposit downwards, for 36 feet, we have argillaceous shale, which was deposited generally in very thin layers of impalpable powder, but in some instances consisted of coarse grains, which from their bluish, greenish grey, and white colours, seem to be heterogeneous in composition, but are still all argillaceous. The colour of these strata throughout would also appear originally to be greenish or bluish grey, which is deepest or blackest where there is most carbonaceous material, although in their upper part they are of a bright brown, or yellow fawn colour, which tints on both sides diminish in intensity as the distance from the line of junction between the volcanic and fresh-water formations increases. Throughout these strata there is an abundance of fossilized vegetable remains; and towards their middle those of animals, such as tortoises, while at their lower part are found the skeletons of frogs. The vegetable remains consist chiefly of the fragments of plants, which at the upper part appear to have been small, but towards the lower part were much larger. In the upper part they have been nearly decarbonized, and replaced by siliceous or argillaceous material of a white, grey, brown, or bright yellow colour, presenting under the microscope in many instances the polygonal or fusiform shapes of their original cellular structures, while towards the lower part they are black and carboniferous. Such as have been found entire, or possessing a recognisable form, will be described hereafter.

The next portion of these strata presents an interlamination of black carbonaceous deposits; this occupies about a foot and a half, when it is followed by two and a half feet of shale, without black layers, imbedding a great number of globular and conical nodules, like *Septaria*, which, on being fractured, generally exhibit the forms of bulbous roots or stems in their interior. These strata, which are the lowest of the undisturbed part of this portion, are harder and more compact in their structure than the foregoing.

We have now an intrusion of bluish or greenish grey coloured volcanic matter, apparently composed of the ingredients of *Trappite*, but all heterogeneously mixed up together, and in the form of argillo-siliceous material, imbedding large portions of carboniferous shale, and, from its napthous odour, impregnated throughout with the remains of vegetable matter. This extends down for twelve feet, or to the bottom of the cut of the sluices. It is, of course, unstratified, and presents a venous intersection, like volcanic rock. The upper six feet is of a lighter colour

than the shale immediately above it, and, although richly charged with small fragments of vegetable remains, contains little, when compared with the six feet below, which are full of large pieces of black argillo-bituminous shale, bearing the remains of large flat long leaves, pieces of dycotyledonous wood, seeds, seed-pods, and various other fragments of the vegetable kingdom, all of a deep black colour, and many sparkling and slightly coal-bearing, though chiefly composed or replaced by argillaceous material.

The coal, which occurs here and there in small granular deposits on the leaves, and about the argillized wood, burns with a bright flame, bubbles up, and leaves a shining black scoriaceous cinder, which lightens a little in colour under the blow-pipe. Also portions of mineral resin, resembling "hatchetine" or mineral tallow, are occasionally met with; and invariably calc-spar in company with both the substances. The mineral resin is sub-granular, like bees' wax, and breaks, but is too waxy to be pulverized; it floats in water, but sinks in alcohol; is translucent, of a weak pearly lustre, and of the colour of bees' wax; feels greasy, and is inodorous; dissolves readily in turpentine, but not in ether or alcohol; becomes soft at a temperature just below 212° Fahr., but does not melt in boiling water; when exposed to a greater heat, becomes very fluid, but does not take fire until the temperature is raised, it then burns away with a bright flame, leaving no residue. Besides vegetable remains, the little *Cyprides* abound in all the masses of this shale; the elytra of insects have been found in it, and the remains of shells something like *Melania*, but all more or less blackened, argillized, and in a carboniferous state.

In no other part of the island has this rich carboniferous portion of the fresh-water strata been observed beyond the depth of a foot or two, affording only a few thin layers of the uppermost argillo-bituminous deposits, viz. those in which the skeletons of the frogs are found. All, therefore, that we know of it is from what has been exposed by the excavation of a few cubic feet at the cut of the sluices, where it has been broken up into fragments by the intrusion of the igneous rock. Nor has the formation generally been seen undisturbed in any part of the island, and, therefore, its maximum thickness is unknown; though no reasonable doubt can be entertained of its having originally been deposited here, on the last of the Primary Trappean Effusions.

Let us now turn our attention to a description of the fossils which have been found in the Fresh-water Strata, beginning first with those of plants.

Roots.

Fig. 1, *a*, *b*, Plate vii., is bulbous, cormiform, ovoid, elongated; truncated above, pointed below; marked with transverse rows of short

vertical parallel striæ, the rows extending more or less round the body, each row tapering towards its extremities, and ending in a point between that above and below it, in the manner of scaly imbrications. Striæ superficial, and sometimes continuous for some way longitudinally. Truncated end presenting concentric lines, like the petiolations of sheathing leaves; pointed end, where fractured, presenting a succession of coats, concentrically disposed. Length of specimen 5 inches; widest transverse diameter 2¼ inches. *Loc.* black shale.

Observations.—These roots are almost lapidified, from the compactness of the argillaceous material by which they have been replaced, They are black externally, where the striæ present the only carboniferous parts about them; and a little lighter coloured within. The rows of striæ shine in the manner of vegetable impressions in clay generally, and the petiolations in the truncated end are marked by delicate white lines of calc-spar. A few *Cyprides* are seen in the interior of these roots, which shows that they must have been widely cellular, or hollow.

Fig. 2, *a*, Pl. vii.—This specimen is of the same description as the foregoing, but appears more globose. The oblique direction of the striæ from above downwards and outwards would also seem to indicate this. Like the foregoing, the striæ are in little bundles, hardly elevated above the surface, and only prevented from being continuous longitudinally by their being raised at one end more than the other. *Loc.* lowest part of the undisturbed shale, and in the intruded igneous matter.

Obs.—These are found in great numbers in that part of the shale just mentioned, and appear very much like *Septaria*. They are less black than the foregoing, thus according more with the colour of the strata in which they are chiefly situated. When fractured, they develope a kind of stem or bulb internally, with its largest or rounded end downwards, that is following the position in which they are found; but the accumulation of adventitious material around them makes it almost impossible to arrive at their original size or shape.

Stems.

Fig. 3, *a*, *b*, Pl. vii., is a section only. Length 1½ inches, and diameter 1$\frac{7}{12}$ inches. Sub-round, slightly striated longitudinally. Truncated end presenting circular lines indicative of the petiolations of sheathing leaves, with the external one of the latter broken off towards the bottom of the specimen. *Loc.* lowest part of the undisturbed shale.

Obs.—This, or rather these pieces of stems, for there are many of them, would appear to belong to the bulbous roots last mentioned. There is very little appearance of a more consolidated portion having existed at their circumference; and internally the presence of *Cyprides* shows that they must have been widely cellular, like the so-called

roots; also the lines of petiolations before mentioned, that they must have been formed of sheathing leaves.

Under this head also comes *fossil-wood*, of which there appears to be a considerable quantity and of various kinds, chiefly dycotyledonous. One specimen met with measured two feet long and six inches broad: it appeared to be a segment of a small trunk; the bark is on it, and, from the infiltration of a lighter substance between this and the wood, and the latter being deficient towards the centre, the whole was probably undergoing decay when immersed. The grain of the latter is distinctly seen, but the soft argillaceous matter which has replaced it, as in most other specimens of the kind, does not admit of a sufficiently fine polish to examine it more minutely. The bark presents externally a number of small projections, and is guttered into large irregular lozenge-shaped divisions.

In one part of the bark was growing a fungus, or portion of adventitious wood, which, on falling out, brought away a part of the trunk-wood itself. It is of a compressed circular shape, about $1\frac{1}{2}$ inches in diameter, and constricted at the base. Many of these kinds of bodies occur in this black carboniferous deposit, and will probably be found to have had the same origin.

No pieces of palm-wood have to my knowledge been found, with the exception of one unsatisfactory specimen; but many small short fragments of wood which possessed a tubular structure, and present a segmental form, like pieces of the common bamboo. The latter occur here and there in almost every part of the fresh-water formation; above, where the vegetable remains are decarbonized, they are of a brown or grey colour, and lower down, where they are carboniferous, of an intense black colour. Besides these, the upper strata present innumerable fragments of small plants, many of which appear to be portions of the stems of grasses. They are all very nearly decarbonized, and replaced by siliceous or argillaceous material, of a white, grey, brown, or yellow colour. Those which are grey present under the microscope a number of polygonal grains or crystals, like the polygonal cells of vegetable structures, while those which are brown and yellow often present the fusiform cellular strueture. The crystals representing the former average $\frac{1}{271}$ inch in length, and $\frac{1}{60}$ inch in breadth; and the argillaceous bodies representing the latter $\frac{1}{43}$ inch in length, and $\frac{1}{2150}$ inch in breadth. Amongst the thousands of little fragments that I have seen towards the upper part of the strata, where they abound in layers, and seldom exceed an inch in length, I have not been able to discover, with the exception of a compressed stem and globular root of some wide grass or bulrush, and two small roundish leaves, which will be presently mentioned, one single fragment possessing a form that could be recognised.

Leaves.

Figs. 4, 5, Pl. viii., are the impressions of the two leaves last alluded to. The largest is oblong and oval, length $\frac{9}{12}$ inch, breadth $\frac{3}{12}$ inch. The smallest sub-round; length $\frac{4}{12}$ inch, breadth $\frac{6}{24}$ inch. *Loc.* upper part of brown shale.

Obs.—These leaves were found among the fragments just mentioned, where there were thousands of other portions, possessing the parenchymatous form of cellular structure mentioned, and, as before stated, without any recognisable form. They look more like leaflets of an acacia, perhaps, than anything else.

Fig. 6, Pl. viii., is the compressed remains just mentioned of part of a long narrow leaf or stem, cracked into fragments, with a tuberous root at the end. Length of specimen $4\frac{3}{4}$ inches, breadth $\frac{1}{12}$ inch; structure fibrous, parallel, longitudinal. *Loc.* brown shale.

Obs.—Three or four specimens of this stem or leaf were found together, but only one with the remains of the root. They are very common, and their cracked state, as well as the cracks which are seen in the flat grey portions of the parenchymatous structure in these remains generally, seems to throw some light on the origin of the infinitude of small formless fragments which pervade these strata, viz. that while the plants from which they were derived were undergoing decompositions, either at the margin or the bottom of the fresh water in which they were deposited, these cracks took place, and, when there was no superincumbent material to keep them in their original position, they floated off, or were otherwise scattered about, and at length finally became stationary in the places where they are now found.

Fig. 7, Pl. viii.—This is a carbonized impression of a scaly leaf or stem in the black shale. It is very thin, and presents elliptical scales, which have their long axes longitudinally; also the transverse cracks to which I have just alluded. Specimen about $4\frac{1}{2}$ inches broad, and 1 foot long. The scale (Fig. 7, *a*) or division consists of an arched elliptical projection, $\frac{1}{24}$ inch long, and $\frac{1}{16}$ inch broad. It is striated longitudinally, and seems to be surrounded with a very narrow flat rim or base, by which it is united to that of the adjoining scales. *Loc.* black argillo-carboniferous shale, in the intruded igneous rock.

Obs.—Only one specimen of this kind has been met with: it was discovered by Dr. Leith, and presents a thin layer of sparkling coal on its surface.

There are many other fragmental impressions of flat long leaves both large and small (Fig. 8, Pl. viii.), with longitudinal striæ more or less perceptible on them, and more or less coal-bearing, in the black argillo-carboniferous shale or deposit; also impressions of large and

small cordate leaves, and an imperfect impression (Fig. 9, Pl. viii.) of two lanceolate leaves, like those of the bamboo, except that they appear to be opposite instead of alternate. Dr. Leith, to whom I am indebted for most of these specimens, also sent me an impression (No. 10, Pl. viii.) closely resembling the stem and flower or seed of a cyperaceous plant, something like *Scirpus lacustris.*

In no instance, to my knowledge, has the impression of any fern been discovered, though I thought at one time I had found the *sorus* of one, which afterwards fell off the specimen, and was thus lost. This was in a portion of the upper light brown-coloured shale, from the tank north of the Horticultural Gardens.

Seeds and Seed-pods.

Fig. 11, Pl. ix., is a small flat capsule, circular, or horse-shoe shaped, with a pedicle rising in the centre, and passing off by the incomplete portion of the ring. It presents a single row of seeds, arranged round the circumference of the disk. Diameter $\frac{1}{10}$ inch. *Loc.* light brown shale.

Obs.—These little discoidal bodies, looking like the magnified ringed capsules of a fern, are not uncommon among the accumulated fragments of vegetable remains in the upper part of the fresh-water strata.

Fig. 12, Pl. ix.—This seed, like that of *Artabotrys odoratissima*, presents the ruminated appearance of the albumen peculiar to the natural order Anonaceæ. Length $\frac{11}{24}$ inch, and breadth $\frac{8}{24}$ inch; compressed, elliptical, and slightly pointed at one end. The ruminated albumen is in transverse lines across the seed, and in radiating ones towards the circumference of the round end. *Loc.* upper brown shale.

Obs.—This specimen was found by Dr. Leith, who pointed out its analogy to the seed mentioned.

Fig. 13, Pl. ix., is a siliquose pod; length $3\frac{1}{4}$ inches, and breadth $\frac{8}{10}$ inch. It is long, sub-round, slightly enlarged towards the apex, which is also round; narrowed towards the stem. *Loc.* black argillo-carbonaceous shale.

Obs.—Close to it lay two other apparently one-seeded pods, of the same description.

Fig. 14, Pl. ix., is another siliquose pod, broken off towards the stem. Length of specimen 3 inches, breadth $\frac{3}{4}$ inch. Long, lanceolate, narrowing a little backwards; angular laterally, presenting a ridge on each side, not opposite; slightly concave on each side the lateral ridge; flat along the sutures. *Loc.* black argillo-carbonaceous shale.

Obs.—For both of these specimens, as well as others of the same kind, I am indebted to Dr. Leith: a vertical section, parallel to the line of suture, has been made in one, but it fails to show anything definite in the interior.

There are a great number of large seed-like bodies throughout the whole of these strata, particularly in their lower part; but they are too undefined to admit of description.

No *nucules* of Characeæ have yet been met with.

Insecta.

Fig. 15, Pl. ix.—*Cypris semi-marginata.* (H. J. C.)—Length $\frac{22}{1000}$ inch, breadth $\frac{14}{1000}$ inch. Ovoid, sub-reniform, compressed laterally at the small end, dilated laterally at the large one; presenting a wide rim round the margin of the valves at the large end, which gives the cast an expanded appearance. This rim is obliquely striated externally, the striæ passing from the convex or posterior border of the shell downwards and forwards. *Loc.* throughout the whole of the fresh-water strata.

Obs.—The obliquely striated rim round the large end of this fossil was pointed out to me by Dr. Leith; and since that I have observed that the prolongation of the valve in this direction is common to the few recent specimens I have yet met with in Bombay. It is likewise striated in them, but the striæ are short, and radiate from the circumference of the valve, instead of passing off obliquely from it, as in the present instance. Neither is the prolongation of the shell in this direction so wide, nor does it extend so much round the valve in the recent as in the fossil specimens. If we look into the interior of the valves of the former (Figs. 18, 19, 20, Pl. ix.), we shall see that the inner margin of the border is extended inwards more or less all round the valve, but more particularly at either end, and, of the two, most at the larger or anterior end, where there is left between it and the outer margin a thin lunate expansion. Beyond this comes a prolongation of or appendix to the valve, in which there is a lunate fossa, or depression, separated from the general cavity of the shell; and this appears to be the portion which is so extensively developed in the fossil species under consideration, on the back or outer side of which are the oblique striæ mentioned. The segment enclosing the fossa or depression, however, in the recent species, instead of being one of a larger, is one of a smaller circle, while that of the fossil species is the contrary, the latter extending round the whole of the posterior or larger half of the shell, and expanding it dorso-ventrally. There does not appear to have been any papillæ on the surface of this fossil species, as on most of the recent *Cyprides*, but these may have been very minute, and may have disappeared during fossilization, or have been rendered imperceptible by the opacity of the object. I have named this species *Cypris semi-marginata* from the character which I have just described.

Fig. 16, Pl. ix.—*Cypris cylindrica?* (Sow.)—Length $\frac{20}{1000}$ inch; and breadth $\frac{11}{1000}$ inch, sparsely papillated. *Loc.* lower part of undisturbed shale, among the frogs' bones.

Obs.—This appears to be *Cypris cylindrica*, which is also found in the chertified lacustrine deposits of the basaltic district of India. (See Malcolmson's Fossils of the Eastern Portion of the Great Basaltic District of India. Geol. Trans. vol. iv. Pl. xlvii. fig. 2, and Pl. ii. fig. 2 of this volume.) It is little more than twice as long as it is broad.

Fig. 17, Pl. ix.—*Cypris* —— ? Length $\frac{19}{400}$ inch, and breadth $\frac{12}{400}$ inch. *Loc.* upper part of fresh-water strata.

Obs.—Of this specimen I have never seen the shell, but an appearance in the mould, as if its surface had been closely and minutely papillated. It is distinguished from the cast of *Cypris semi-marginata* by not having the impression of the rim mentioned, and is therefore not so expanded dorso-ventrally; nor is it so prominent transversely, towards the large end, as *Cypris semi-marginata*.

The three fossil *Cyprides* above described swarm throughout the fresh-water formation. I have already stated that within three inches of the overlying *Basalt* there is a stratum of their casts three inches thick, not of one valve only, but of the whole shell, and the probability that this was occasioned by some sudden alteration of the water in which they lived. When most abundant, their shells are found in thin layers, which, being frequently separated from each other, would seem to point out that they had been deposited in great numbers at particular periods. In the upper part of the strata they are always more or less mixed up with small remnants of vegetable matter, while lower down the fossil skeletons of frogs are sometimes found upon the flat surface of the black carbonaceous shale on which they have been deposited. They are also found abundantly throughout the woody deposits, and entire in the interior of the roots and stems mentioned; in short, as I have stated, they almost swarm throughout the whole of this formation.

They would appear to have their corresponding forms in the three most common cyprides now found in the fresh-water accumulations of Bombay to which I have just referred, but the latter are much larger, as will be seen by comparing their relative sizes in the drawings, all of which have been delineated upon the same scale. Fig. 18 is sub-globular, tetraedral; prominent laterally; flat ventrally; sub-pyramidal dorsally; covered with minute papillæ supporting short spines or hairs. Length $\frac{30}{400}$ inch, breadth $\frac{22}{400}$ inch. Fig. 19 is elongated; cylindrical; slightly incurvated ventrally; sparsely covered with large, and thickly beset with minute papillæ. Length $\frac{36}{400}$ inch, breadth $\frac{15}{400}$ inch. In both these specimens the borders of the valves present a substriated or milled appearance, particularly over the prolonged portion of the posterior or large end. Fig. 20 is sub-reniform, and covered with large papillæ almost touching each other. Length $\frac{26}{400}$ inch, breadth $\frac{14}{400}$ inch. This has also the prolongation of the valve posteriorly.

Fig. 21, Pl. ix., is the right wing of a small coleopterous insect, one of two specimens found by Dr. Leith. It is $\frac{1}{10}$ inch long, and presents parallel longitudinal ridges, with rows of puncta along their course, and transverse wavy lines across the ridges. *Loc.* black shale.

Obs.—This fossil is carbonised, and under it was found a layer of calc-spar, apparently the remains of the transparent wing; beneath which again were the ridged impressions of the under part of the elytra.

Fig. 22, Pl. ix.—This is the remains of a shell like *Melania*, which was conical, elongated, composed of five whorls, the latter costated transversely. Length $\frac{11}{24}$ inch, and breadth $\frac{5}{24}$ inch; total length of the impression $\frac{14}{24}$ inch; the additional length does not appear to have been caused by a part of the shell, though by something belonging to it. *Loc.* black shale.

Obs.—The specimens of this fossil are very indistinct, and formed of the same material as the black carboniferous shale in which they are imbedded. There are other impressions of a smaller shell of the same kind, but with a rounded apex, like that of *Pupa:* all were found by Dr. Leith.

In the chert of the upper strata, containing an abundance of *Cyprides* with fragments of plants, the section of a roundish shell, something like *Paludina*, was found.

Reptiles.

Rana pusilla.—This is the name which has been given by Professor Owen to the fossilised remains of the skeletons of the frogs to which I have had occasion to allude. The following is Professor Owen's description of them, which will be found in the Quart. Jl. Geol. Soc., vol. iii. p. 224, taken from specimens given to Mr. Clarke by Dr. Leith, who was the first person that discovered them :—

"The portions of shale transmitted by Mr. Clarke contain delicate but for the most part distinct traces of the generally entire skeleton of small anourous *Batrachia;* the osseous substance is black, as if charred.

"The number of vertebræ, atlas and sacrum inclusive, is nine; the caudal vertebræ are fused into a long, slender, cylindrical style, as in most anourous *Batrachia.*

"In the specimen (Fig. 1) which lies on its back, the posterior convexity of the vertebral bodies is shown.

"The short, sub-cylindrical, and very slightly expanded lateral or transverse process of the sacrum, and the absence of ribs or their rudiments in the dorsal vertebræ, with the proportional expanse of the skull and length of the hind legs, show the specimens to belong to the family of Frogs (*Ranidæ*).

"There are seven abdominal vertebræ, with long and sub-equal trans-

verse processes, that of the second (third vertebra including the atlas) being the longest. The humerus is cylindrical, not expanded, as in *Cystignathus.* The head is a little larger relatively than in *Rana temporaria*, *Rana esculenta*, or *Hyla viridis;* and still larger therefore than in the Toads and Natterjacks (*Bufonidæ*), or than in the *Pipa;* the expansion of the sacrum removes the genus *Pipa* and the *Bombinatores* from that of the present fossils. The following are admeasurements of the more perfect specimens :—

	Inches.	Lines.
Length from front part of head to symphysis pubis	0	6½
„ of the head	0	2¾
„ of the dorsal vertebral series	0	2¾
„ of os innominatum	0	2½
„ of femur	0	2¾
„ of anchylosed tibia and fibula	0	2¾
„ of tarsus	0	1¼
„ of whole foot	0	4½
„ of whole anterior limb	0	4

"All the specimens belong to individuals which had completed their metamorphosis, and they are similar to one another in size; they may have belonged either to a not quite full-grown brood, or to an unusually small species, of *Rana.**

"They conform in all respects as closely to the typical organization of the Frogs of the present day, as do the fossils discovered by Goldfuss in the tertiary lignites of the Siebengebirge, and referred by him to *Rana diluviana;* but the Bombay batracholites differ not only in their smaller size, but also in their proportionally larger skulls."

In most of these skeletons the teeth may be seen, and the bones are found (as Professor Owen has stated) in a charred state, in the black shale, which at the Sluices exists in separate layers, towards the lower part of the undisturbed portion of the fresh-water formation. They have not, however, yet been found *in situ;* but their position is inferred from the character of the shale in which they are imbedded. Generally the skeleton is entire, with the extremities more or less flexed, as they would be in a dead frog; and they lie flat on the black mud on which they have been deposited, alone, or amidst layers of cyprides. They abound at the Sluices, and in black shale excavated from wells on Malabar Hill, three miles off; and appear to be confined to the part of the fresh-water deposits mentioned; but are there found in different layers. In one specimen of black shale, which is $\frac{1}{10}$ inch thick, and composed of six

* Part of the posterior extremities (*tibiæ*) of a larger frog have since been found in the same shale by Dr. Leith, which he computes to have belonged to a frog about three inches long. They are in the Museum of the Bombay Asiatic Society.

layers, they appear on every layer; in another specimen, belonging to Dr. Leith, they are on layers an inch apart, a deposit of brown shale half an inch broad intervening between the black carboniferous layers; and in one instance, in and around a disturbed and broken up portion of black shale, I have met with their bones scattered with *Cypris cylindrica*, (?) in the heterogeneous-looking argillaceous deposit, probably of igneous origin, intercalating and surrounding that shale; while in the unbroken part of the shale itself the skeletons are entire, and the disposition of the bones the same as that in parts where they have been undisturbed. That the enveloping material here is of igneous origin is proved by its bluish or greenish-grey colour, its heterogeneous-looking appearance, its argillaceous nature, its massive and unstratified form, and effervescence with acids. Hence it seems probable that in breaking up the black shale it swept off the loose bones of the skeletons, and carried them into the positions mentioned. Had it been otherwise, viz. that the igneous matter had flowed into the fresh water, and killed these animals, then there would have been no broken up black shale present, with the undisturbed skeletons entire in it; for the former would have overflowed the latter, and not have intercalated it. But this will be better understood when we come to consider the igneous effusion which has intruded these strata.

Testudo Leithii, n. j. c. (Plates x. and xi.).—The remains of nine specimens of this tortoise have been found by Dr. Leith, and the following description has been taken from them:—

Carapace (Pl. x.).—The 1st dorsal plate is pentagonal, almost quadrilateral, with two irregular sides in front, meeting at an extremely open angle, and behind a border slightly concave anteriorly; its lateral boundaries are rectilinear and divergent. 2nd dorsal plate about twice the size of the first; hexagonal; half as broad again transversely as it is antero-posteriorly; posterior border suddenly convex forwards in the centre, and longer than the anterior border; lateral borders undulous, and meeting at an obtuse angle outwardly. 3rd dorsal plate one-tenth less than the second; hexagonal; nearly twice as broad transversely as it is antero-posteriorly; posterior border abruptly convex forwards in the centre; much less in length than the anterior border; anterior lateral sides convex outwards; posterior lateral sides convex inwards, both meeting at an obtuse angle laterally. 4th dorsal plate a little more than half the size of the third; hexagonal; contracted posteriorly; posterior border straight; antero-lateral sides also straight, and short; postero-lateral convex outwards, both meeting in an obtuse angle. 5th, or last dorsal plate, heptagonal, triangular, with the apex truncated: contracted in front; presenting posteriorly four sides, which unite with the two supra-caudal, and half the two first femoro-marginal scales; lateral sides rectilinear.

Antero-costal plate tetragonal, sub-triangular. 2nd costal pentagonal, its two inner sides forming an obtuse angle upwards. 3rd costal quadrilateral. The last pair of the costal ranges are broader above than below, and present six sides, by the three smaller of which they articulate with the marginal plates which correspond to them.

Marginal scales 24. Marginal collar and first brachials sub-quadrilateral, longer than broad; second brachial pair trapezoidal; supra-caudal sub-square, trapezoid; first and third margino-femoral pairs pentagonal, the latter longer than broad; the intervening ones square; fifth margino-lateral oblong, broader behind than in front. Of the other margino-lateral scales there are no specimens.

Plastron (Pl. xi.).—Plane elliptical; round anteriorly, and notched in the centre posteriorly, but not deeply; intergular plate four times larger than the gular, and pentagonal, sub-triangular, the two posterior sides meeting at an obtuse angle: gular plates resemble isosceles triangles, with their posterior edges a little bent outwards, towards the apex. These three anterior plates are locked in between the brachials, which resemble scalene triangles; they are not so large as the intergular plate. The portions of the pectorals and abdominals which cover the sternum present square figures. The femorals are quadrilateral, having their internal lateral border less than their external lateral one, which is slightly convex on the outer side. The anal plates are triangular and rounded exteriorly, and cover that part of the sternum to which the pelvis is soldered. (See plate.)

Where the axillary and inguinal scales might have existed the parts are imperfect, but there do not appear to have been any.

The head appears to have been triangular and flattened, unless this arises partly from pressure, and the nostrils obtuse; there is a deep gutter extending from the muzzle backwards, becoming superficial as it approaches the superior occipital bone. The orbits themselves are directed upwards.

The pelvis is soldered in front to the sternum, and the tail appears to have been so short that it only just extended beyond the ilia. Fortunately the point of it remains in one specimen in that position.

Dimensions.—Length of carapace $7\frac{1}{4}$ inches, breadth in its flattened state 6 inches. Length of plastron 7 inches; breadth at inguinal angles about $2\frac{7}{8}$ inches, and breadth in the centre about $4\frac{6}{8}$ inches.

Head.—From the nasal extremity of the anterior frontals to the basilar bone $1\frac{10}{12}$ inch; distance between the posterior angles of the orbits $\frac{1}{12}$ inch; distance between the anterior angles of the orbits $\frac{4}{12}$ inch; distance between the posterior angle of the orbits and the extremity of the mastoid process, which is prolonged backwards, $1\frac{5}{12}$ inch; width between the condyles of lower jaw $1\frac{1}{2}$ inch. *Loc.* The remains of these

tortoises were found in the shale excavated from the undisturbed part of the fresh-water formation at the Sluices. Dr. Leith, however, is under the impression that one of the specimens came from a pit in the eastern side of the flats just opposite. They have not been found *in situ*, but appear to have come from the middle of the undisturbed strata.

Obs.—Thus, it will be seen, from the pelvis being soldered to the plastron, that this tortoise belonged to the *Pleuroderal Elodians* of Dumeril and Bibron, none of which are now found in Asia; and from the absence of the nuchal plate, that it belonged to one of their first five genera. Also from the form of its scales generally, as well as the shortness of the tail, that it came nearest the genus *Sternotherus*, and of the species of this genus nearest, in the form of its scales, to *S. castaneus*. (Dumeril et Bibron Erpétologie Générale, vol. ii. p. 401.) It differs, however, from the latter species in the anterior lines of the pectoral scales of the plastron being parallel with those of the abdominal scales, instead of meeting at an angle backwards. In size it agrees exactly with the length of the carapace of *Sternotherus niger;* the plastron is also very nearly as large as the carapace. In the specimen from which the drawing has been chiefly taken, the plastron has been probably pushed forwards out of its original position, by the pressure to which these parts have been subjected during fossilisation: in all the specimens both carapace and plastron are in contact. The horny parts of both, marked externally with their intricate network of grooves, as well as the outer layers of the bones themselves, are all charred, while the cancellous structure of the internal parts, being filled with calc-spar, presents its original appearance. Above are described all the parts of this tortoise which admit of it: the remains of nine individuals, as before stated, have been found, all very nearly of the same size, and all by Dr. Leith, after whom I have named it, and to whose general attainments and acute observation we are indebted, not only for bringing to light the existence of the remains of this animal in the fresh-water strata of Bombay, but for almost every other valuable specimen that has been obtained from them,—thus claiming, in fact, the merit of having first directed the attention of the public to this interesting formation.

Distribution of the Fresh-water Strata.—Having described the upper strata of the fresh-water formation where they are best seen, and a few of the fossils which have been found in them, let us now trace them throughout the other parts of the island. I have already stated that they are overlain by the *Trappito-basaltic* tract, and that this tract in the first instance was probably continuous all over the island, but that it has since been broken up into the ridges already described, and much of the parts which intervened carried away by denudation. Hence, it may be conceived, that the same agent which threw up these ridges also threw

up at the same time more or less of the fresh-water strata which lay beneath them, and that therefore the latter will be found exposed on the scarped sides of, as well as in the plains between, these ridges, where the *Trappito-basaltic* tract has been uplifted or removed. That such are the facts will presently become evident.

Beginning with the ridge on the outer side of the island, called Malabar Hill, we naturally look, in its scarped or eastern side, for the strata in question, and there we find them overlaid by the *Basalt*, which in some parts is 50 feet thick; while they are completely hid on the other or western side, where the *Basalt*, which at first slopes suddenly over them, afterwards, as before stated, extends outwards into the sea at a very small angle of inclination. If we commence, then, from Malabar Point, which has been stated to be the southern extremity of the outer ridge of the island, we shall perceive these strata on its eastern side appearing just above the water's edge about 50 yards in; they are easily distinguished by their light brown or fawn colour, which contrasts strongly with the black *Basalt* above them. Following them northwards, we find that they gradually increase in thickness as the ridge rises; but after two-thirds of a mile suddenly become contorted and twisted into all kinds of shapes, indicating that at this part, which extends for about 300 yards, they have undergone more disturbance than at any other, and a short search shows us that it has been caused by the intrusion of an igneous rock. It was from the contents of a well excavated at this spot that the specimen of black shale and igneous matter, containing the bones of the frogs in a scattered state, was obtained. After this disturbed portion, the strata again resume their parallelism, and may be traced along the whole of the eastern side of Malabar Hill to Mahaluximee, where there is a break in the ridge of 1,000 yards, extending from the place last mentioned to Lovegrove Point or Mama Hajanee, from whence the ridge is again continued on to the Sluices, where there is a second break, about 250 yards wide, and where the cut of the Sluices, which extends from the "Flats" to the sea, exposes the section from which the foregoing description of this formation has been chiefly taken; and from which the principal part of the fossils mentioned has been derived. From this break on to Worlee Fort, or the northern extremity of the outer ridge, the fresh-water strata may be again traced, cropping out from the scarped portion of the *Basalt*, and at the latter place may again be seen to be intruded by igneous matter.

Throughout the whole of this ridge they present an anticlinal elevation, one side of which dips more or less to the west, the other to the east, becoming almost horizontal again at the base of the ridge, where they extend, concealed under the *Basalt*, into the sea on one side, and, exposed, over the "Flats" on the other. At the Sluices the dip of most

of the strata on the west side of the anticlinal axis is more than 45°, and on the east side would appear to be the same, but is obscured by the Sluices; while the intruded igneous matter is seen filling up the angle of the arch thus formed, as if it had been the disturbing agent.

We now come to the "Flats," and here the fresh-water strata are not continuous any more than the *Trappito-basaltic* tract, both having, apparently, been broken up together, and suffered a like denudation: it is only here and there that a portion of the fresh-water strata is seen entire, being for the most part mixed up with intruded igneous matter, or entirely transformed by decomposition; but, on passing across the "Flats," we again find them here and there, overlaid by the *Trappite*, and hence we may expect to find them exposed again in the scarp of the eastern ridge in a similar manner to that we have seen on the western ridge, for, tracing them where they are yet entire on the eastern side of the "Flats," viz. at the end of the Grant Road, we find them 600 yards further due east, viz. in Baboola Tank, underlying the *Trappite*, as before stated; and again, 650 yards still further, in the scarp of the quarry on the eastern side of Nowrojee Hill, but here in a thin line, either on account of the intruded igneous rock having merely separated a foot or two of the upper part of this formation from the rest, or from the pressure of the incumbent *Trappito-basaltic* tract, which is here very thick. In Baboola Tank these strata, which are only five feet thick, are seen to have only four feet of *Trappite* left above them, while in Nowrojee's quarry they have 90 feet. Again, after tracing this formation across the "Flats" opposite Parell to the eastern side of Parell Tank, we find its strata appearing in the wells there also, with only a few feet of *Trappite* above them; and, if we cross over the hill, we shall find them cropping out again on its eastern side. Thus they are seen to pass across the "Flats," and to appear again on the scarped side of the eastern ridge, proving that they have been everywhere superposed by the *Trappito-basaltic* tract.

Let us now go to the scarp of the eastern ridge, and follow these strata northwards, from Nowrojee's quarry, where, as before stated, they are reduced to a thin line. For some distance after this the state of the hills, from being covered more or less with grass, does not permit of our seeing them satisfactorily, but when we come to the southern extremity of Chinchpoogly Hill, the thin stratum, composed of the casts of *Cyprides*, with fragments of plants, which I have before stated to mark the upper boundary of this deposit, is again recognised, immediately underlying the *Trappite*, and not more than 30 feet above high-water mark. This stratum, in a broken, black, basaltified state, may thence be traced for 900 yards, rising all the way, until it is elevated by a subsequent igneous effusion to the crest of the hill itself. From this we may trace these strata on to Parell Flagstaff Hill, and thence to a tank beyond

the Gardens, where they exist in very thin layers, making in all 16 feet thick; wavy from disturbance, and dipping, as usual, greatly towards the west. They are here richly charged with fragments of plants, and the casts of *Cyprides*, but do not present a single black carboniferous lamina; although immediately on the other side of the ridge opposite Parell Tank there are portions of interlaminating black bituminous shale which have been excavated from the wells there, just like those which are obtained from the wells at Malabar Hill and the Sluices, in which the frog-skeletons are found.

From the former tank the fresh-water strata are continued northwards through a valley, over an area of upwards of a mile long, and from two to three hundred yards broad, uncovered by the *Trappite* as in the "Flats," and forming a horizontal plain between the first and third eastern ridges, already described, until they reach the village of Nagaum, on the road to Sion, where they join the strata on the "Flats," and the main ridge of *Trappite* is for a certain distance reduced almost to a few boulders.

This formation may again be seen in the valley between Kandlee Battery and Jackaryah's Bunder, that is, between the second and third eastern ridges, passing up to the tank at the north of the Gardens, and in its way exposed in a large excavation to the depth of 16 feet, dipping, as usual, towards the west. Lastly, this formation may be seen again on the eastern side of the third ridge, extending northwards from Jackaryah's Bunder, more or less broken up, to Sion, at the northern end of the island.

From what has been stated, then, two facts are now evident, viz. that there is a fresh-water formation, and that it is partly overlaid by the *Trappito-basaltic* tract, or 1st of the Secondary Volcanic Effusions, which was once continuous, and probably horizontal. After this, a third fact becomes evident, viz. that there must have been some subsequent cause to throw up these two formations, at first parallelly and horizontally applied to each other, into their present ridges. The consideration of this cause brings us to the description of the intruded igneous matter or 2nd of the Secondary Effusions.

Second Volcanic Effusion.—I have already alluded to the presence of igneous rock among the contorted strata, a short distance in from Malabar Point; that it is seen again at the cut of the Sluices, and again at Worlee, the northern extremity of this ridge; also in different parts of the "Flats," &c.; but I have designated this effusion by no particular name, for when we remember that it has flown in between the aqueous strata, breaking them up into fragments, bruising them into powder, and more or less amalgamating with them, we cannot wonder that in one place it should have assumed one form and in another another, depending upon the quantity of foreign material with which it has become mixed. Hence it will be necessary to go to that

place, or places, where it is most pure, first, and ascertain its original character. For this purpose let us begin with it at Nowrojee Hill, where it is 40 feet thick, and apparently as pure as when it first came from the volcano. Here it underlies the thin line of fresh-water strata mentioned, in the form of *Trappite*, differing so little from that above this line, that, until we compare the two closely, their distinguishing points do not become appreciable; when, however, this is done, the chief difference is found to consist in the presence of a greater proportion of argillaceous earth, which renders it softer and more easily yielding to the hammer, and this, together with its deeper blue leaden colour, enables the quarrymen to recognize portions of it immediately, when a passing observer would not know whether they belonged to the *Trappite* above or below the fresh-water stratum. This is the state of this effusion, I presume, where it is seen intercalating the aqueous strata below Dr. Buist's house, or nearly opposite Sewree, but the part exposed there is decomposing into spheroids, and too far advanced to satisfactorily exhibit by fracture its original state. In Baboola Tank, and at the tank north of the Horticultural Gardens, it is an amygdaloid *aphanite*, with a greenish-coloured base, the cavities being filled with laumonite, which is surrounded by green-earth, and which substance in many places seems to become a pseudomorph of laumonite. On the Chinchpoogly part of the eastern ridge, just behind the house called Lowjee Castle, where there has been an outburst of a still later effusion, the cavities of the former, which is decomposed where it remains on the upper side of the latter, are partially or wholly filled with quartz crystals; large crystals of hyalin and amethystine quartz from crushed geodes are also seen in it: while on the lower side of the dike the cavities of the amygdaloid are filled with green-earth in a fresh green, and decomposing brown, rock. They are also filled with quartz in the neighbourhood of Sindu Para; in an area of about half a mile square, on the western side of Ghorpadevi, towards the "Flats," where the rock is brown coloured; and, further north again, with green-earth, that is to say, in the neighbourhood of the house called Lowjee Castle. On the eastern part of the "Flats," nearly opposite Parell, the cells are filled with calc-spar, and for several feet down the rock is a brown *spilite*, (base *aphanite*, filled with crystals of calc-spar,) imbedding pieces of the aqueous strata towards the surface, which become less downwards, and the rock, becoming blue, at length passes into *Trappite*. In some parts this rock is veined with calc-spar, and in others presents geodes or large cavities, filled with large lenticular nail-headed crystals of the same, resting on their edges. Still further north, again, at Dharavee, this effusion is of a light yellow or fawn colour, and is commonly called "White Trap." There is a large tract of it here, and in many parts,

where it is amygdaloidal, the cavities are filled with a soft fine white clay, like white green-earth, which seems to be the ultimate pseudomorph of laumonite here.* In the museum of the Asiatic Society there is a radiated mass of scolezite, passing into a fine flesh-coloured greasy pseudomorph, very like pagodite; and also several massive varieties, which have lost their crystalline appearance, and have assumed a compact structure, which is opaque, white, and greasy to the nail; so that this passage of a zeolitic mineral into fine soft clay seems not to be uncommon. Crossing to the western ridge of the island, we have this effusion, as before stated, amidst the aqueous strata, apparently possessing all the ingredients of the blue *Trappite* seen in the quarry at Nowrojee Hill, but without the semi-crystalline structure. The blue earth is evident, but the rest of the ingredients have taken on an earthy, argillaceous state, and have become more or less impregnated with calc-spar, which causes this rock to effervesce when touched with nitric acid. From the wells on Malabar Point it comes out partly in the form of a clay rock of uniform fine structure, and blue colour, still effervescing with nitric acid. In some portions of this there are small angular fragments of a white colour, which seem to be parts of the fresh-water strata, and thus identify this breccia with an effusion which by-and-bye we shall find widely spread on the other side of the island. At Worlee, where this rock is exposed, it is of a bright red brick colour, and filled with fragments of the preceding formation; and at the Sluices it is of a bluish colour, and envelopes large masses of carboniferous shale, besides being impregnated throughout with a naphthous odour; while between these two places it is found in a decomposed amygdaloidal state. Where it appears on the sea-shore, at Malabar Hill, pieces of empty scoriæ are imbedded in it—the only instances of the kind I have met with in the island of Bombay. At the cut in the Sluices this rock is seen filling the internal angle of the anticlinal elevation of the aqueous strata; appearing, as before stated, to have been the agent by which the whole of this ridge has been elevated. It is seen in many parts of the "Flats" much in the

* Here also may be seen an instance of what occurs in the Deccan on a more enlarged scale, viz. the replacement of calc-spar by quartz. Many of the cells are partly filled by the former, which is evidently giving way to the formation of minute hexagonal prisms of the latter. I also found milk-white calcedony here combined with "green-earth" equally rich in colour to any I have seen from the Deccan.

Nicol, in his Mineralogy, classes "green-earth" with the "clays." Phillips places it under "chlorite." Hauy's name for it was "talc zographique." Dana writes, "The green-earth occupying cavities in amygdaloid is near *chlorite*. It is a silicate of the peroxyde of iron with some potash, magnesia, and water." In the museum of the Asiatic Society there is apparently a large tabular crystal of it on a piece of granitic rock, which has all the sectile greasy characters of chlorite together with the colour of deep-green "green-earth." I have added this note because many think that the green mineral of the Trappean Rocks in the Deccan must be a compound of copper.

same state as in the western ridge, having, in short, intercalated and broken up the fresh-water strata more or less throughout the island. North of a line extending from Parell to Worlee the whole of the "Flats" under the clay is covered with the thin stratum composed of the casts of *Cyprides*, which has been chertified, and rendered more or less jaspideous by heat; thus affording a serviceable material for forming the surface of the railway in this part of the island.

Hence we have seen, that the 2nd-effusion in its purest form at Nowrojee Hill is *Trappite*, and that it passes into *aphanite*,—the latter may be seen taking place within a few yards, in some small tanks and excavations on the eastern side of the railroad, towards the middle of the island. We have also seen the *Trappite* in other places passing into an amygdaloid, the cavities of which are filled either with laumonite, quartz, green-earth, calc-spar, or fine white clay (decomposed laumonite?), according to the locality; also that in some places it contains more or less fragments of the aqueous strata; is sometimes a blue compact hard clay; sometimes a breccia; and, last of all, that it may have an earthy or crypto-crystalline base, coloured blue, green, brown, yellow, or red.

We do not see the *Trappitic* or amygdaloidal form of this effusion anywhere breaking through the *Trappito-basaltic* tract; at the same time we see it interlaminating to a great degree the fresh-water strata; from which it may be inferred that it was thrown out under a great weight, and that this superincumbent weight was the *Trappito-basaltic* tract itself. But for this extensive interlamination, it might have been doubtful whether it had not been thrown out while yet the aqueous strata were in process of being deposited, and that there was then an interval again, during which more aqueous strata were deposited; and, last of all, the *Trappito-basaltic* tract poured forth over the whole. It is, however, almost impossible that, in such loose soft strata as those composing the fresh-water formation, an interlaminating intrusion of the igneous rock should take place to such an extent as we see it, without the presence of a superincumbent weight, such as the *Trappito-basaltic* tract must have formed; it would rather have burst through the whole of the thickness of these strata in the form of a great dike, and then have overflowed them. On the other hand, its amygdaloidal form chiefly distinguishes it from the *Basalt* and *Trappite* of the *Trappito-basaltic* tract. The late Captain Newbold has observed respecting the Trappean Effusions and *Diorite* (Jl. As. Soc. Bengal, vol. xiv. p. 204), that in the Southern Maratha Country, the *Diorites* "are distinguished mineralogically from the tertiary or overlying traps, by their rarely assuming an amygdaloid character, and their freedom from agates, opals, calcedonies, zeolites, green-earth, olivine, &c. so abundant in the latter."

Thus the third fact becomes evident, viz. that the second effusion was

one cause, if not the first and principal, of the displacement of the Fresh-water Formation, and the *Trappito-basaltic* tract.

Third Volcanic Effusion.—We have now a fourth fact to establish, and that is the occurrence of a third volcanic effusion, by which the strata of the Fresh-water Formation and other rocks have been thoroughly broken up, and converted into a Volcanic Breccia, forming a large tract. This tract extends from Carnac Bunder to Sion Causeway, and forms the entire of the chain of hills bordering the north-eastern end of the island, from the Fort of Sewree to Sion, inclusive. It would be difficult to prove that it was a subsequent effusion to the last mentioned, were not large portions of both the *Trappito-basaltic* tract and the amygdaloidal effusion mixed up with the fragments of the aqueous strata contained in it. But the presence of the amygdaloid alone places this beyond a doubt.

Let us now trace this Volcanic Breccia throughout its whole extent; but, before doing so, it would be as well to premise that the igneous matter binding together its fragments is *aphanitic*, and for the most part of a white colour, speckled with brown, but passes from blue, which is probably its original colour, to green, yellow, brown, red, and, lastly, black, varying according to its compactness and extent of decomposition. It is generally earthy, sometimes where decomposed sandy, and in some parts hard or wholly jaspideous.

Commencing from Carnac Bunder or its southern extremity, we find this effusion for the most part white, and extended over a large area, which is covered by the sea at high tides. Large fragments of the Fresh-water Formation are here seen imbedded in it, as well as fragments of the other rocks, some of the former six feet long, and still retaining their thinly laminated appearance, and so plentiful that the whole mass assumes a dark colour from their presence, but this will be found to be confined principally to the surface. Tracing this Volcanic Breccia northwards, we find it passing under Mazagon Hill, the base of which it forms; and the wells in it on the northern side, extending downward for 60 feet without passing through it, show how thick it is. Here, also, we see that the brecciated part is chiefly confined to the surface. The newly excavated contents of these wells also show that some way down this effusion is extremely white, like lime, but it is chiefly composed of silex: when I was examining them some people were taking portions away to whitewash their houses. In some parts also it is mottled blue and green, or red, and in structure and nature is granulo-pastic. We now find it bordered on the eastern side by the second *Trappitic* ridge, which probably overlies it; and in the neighbourhood of Tank Bunder its brecciated form appears in perfection. All the rocks of which it is composed are here seen in large masses, or in comminuted fragments, varying in size with the locality, and with the coarseness of the breccia; but what is

most remarkable is its separation in some parts into polygonal or prismatic divisions, at once proving that it is of volcanic origin. From Tank Bunder it may be traced on to Chinchpoogly Hill, keeping principally to the shore, and thence to Jackaryah's Bunder, where it assumes the form of sand of a yellow colour, imbedding large fragments of the aqueous strata in a red or black jaspideous state. From thence to under Dr. Buist's house, nearly opposite Sewree, it may be seen passing in between the less disturbed aqueous strata which here lie beneath the second effusion; and on arriving at Sewree itself we come to the tract of it which extends uninterruptedly to the northern end of the island, forming every hill and mound between Sewree and Sion; thus covering an area of about three and a half miles long, and in its broadest part three-quarters of a mile wide. It will surprise the observer at first to find that it assumes the appearance and structure of a coarse black homogeneous jasper at Sewree; but, if he examines this carefully, he will see in parts of it which are washed by the waves, large fragments of *Trappitic* and amygdaloidal rock; and when he comes to approach Antop Hill from the west, which is still more homogeneous and jaspideous, he will find that he walks over the light-coloured Volcanic Breccia first, and then over a blacker and blacker coloured, until the fragments of stratified rock become mingled more and more with the igneous effusion, and at length disappear altogether, giving place to the homogeneous composition mentioned. It was here, in the plain between the village of Wadalla and Antop Hill, that Dr. Leith pointed out to me, in a group of semi-jaspideous black rocks, a large piece of coarse-grained white crystalline *Diorite*, looking at first sight like granite or syenite, also many portions of *Trappite*, much larger in grain than any which is to be found on the surface of the island of Bombay *in situ*. These, then, must have been brought up from a depth by the igneous effusion, and it may be questionable whether they are not portions of the rock on which the Fresh-water Formation rests. Striking as the gradual passage just mentioned of the Volcanic Breccia from one state into another may appear, the sudden transition of the black jasper of Antop Hill into the light-coloured breccia of the one adjoining it is much more remarkable, for in the latter instance you may almost put one foot on one and the other foot on the other, though they belong to the same effusion. After Antop Hill all the others in this neighbourhood, some upwards of 130 feet high, are composed of a light reddish-coloured breccia, compact externally, that is where it is not decomposing. In some parts the fragments composing it are all small, and in others large and small, but all sharply angular. Here and there, also, may be seen polygonal divisions on the surface, indicative of the prismatic form common to basaltic rocks. I am led to believe that this breccia forms a great part of the mountains in

Salsette, and indeed have seen it not only forming those of the middle but those also of the northern and southern extremities of this island.

Let us now return to the neighbourhood of Mazagon, where the *Trappite* remains continuous over a larger area than in any other part of the island; and here we shall find that almost all the wells pass through it into this white brecciated effusion. Where this is not the case, they are more or less veined or diked with it, and in several places we may observe that it has broken through the *Trappite*, and spread itself for a short distance over its surface, showing clearly that it must have been a subsequent effusion to the *Trappite* at least. Indeed, when we come to consider that the *Trappite* overlies the aqueous strata, we can easily conceive how it should be underlaid by the second and third igneous effusions, which have followed the course of these strata; but it is only the latter effusion which seems to have burst through the *Trappite*.

We have now traced this effusion coming from under the base of the eastern ridges throughout its whole length; and we have seen it forming the plain and hills in the north-east part of the island; we have also seen it forming the lower part of the wells in the *Trappitic* tract of Mazagon, and we have seen it veining and diking, and at last bursting through this rock in the same locality; but we have still another place left to examine it, where it forms half the ridge between Chinchpoogly and Parell Flagstaff Hill. Here it begins to issue 600 yards south of the latter from a dike, which descends rapidly on the eastern side of the ridge, separated from the *Trappite* above by about six feet of amygdaloid, belonging to the second effusion, to which I have already alluded (page 146), and below by the same amygdaloid, partly in a fresh and partly in a decomposed state. The Volcanic Breccia here is chiefly composed of the white powdery *aphanite* before mentioned, with brown specks; the former melting into a white porcelain globule with borax, the latter attracted by the magnet, after exposure to a white heat. It contains but few fragments of the other rocks, and its chief peculiarity—that, indeed, which distinguishes it from all other effusions of the island—is that it is filled with cells which are elongated horizontally, as well as large and small geodes, which contain crystals of hyalin or amethystine quartz, calcedony, or agate. The geodes are for the most part compressed vertically, and some are a foot in length, and contain crystals an inch long, and proportionally thick; the rock is decomposing, and the cells and geodes, which have been filled by infiltrated agate or calcedony, are lying about the neighbourhood, affording a good example of the way in which the so-called agate and cornelian mines are formed. This rock, which issues at the point mentioned, is continued on, forming the eastern side *only* of the ridge for some distance, when it crosses it

diagonally to attain the western declivity of Parell Flagstaff Hill, down which it extends for a short distance, and there ends. Just at this part the road from the Horticultural Gardens to Parell passes over it.

One observation only remains for me to state respecting this effusion, viz. that there is a dike of it seen passing up through the westernmost of the hills at Sion, through the base of which the railway has been cut, and by which its existence has been made evident. It contains portions of the fawn-coloured amygdaloid of the second effusion ("White Trap"), which, it will be remembered, exists close by in a large tract at the village of Dharavee. The cellular cavities of the fragments are also filled with the fine, white, greasy earth which I have stated to be a pseudomorph, if not a decomposed form, of laumonite. This dike, which is 16 feet wide, and rises at an angle of 80°, is inclined towards the south, but, from the red colour of the breccia through which it passes, it is fast becoming discoloured, and in a short time will be undistinguishable on the surface from the rest of the rock. There is another dike of it in a cut of the road towards Trombay, just on the other side of the Causeway, in the island of Salsette, which is two and a half feet wide; it has a nearly vertical direction, and passes between the *Trappite* on one side and the red breccia on the other. These dikes, then, constitute a *Fourth Effusion*, from their passing through the third effusion.

In all the effusions subsequent to the *Trappito-basaltic*, calc-spar abounds more or less, which is not the case with the latter, in which it is rarely if ever seen. In the blue amygdaloid *aphanite* at Baboola Tank it is common in large cavities, with laumonite, occurring massive or in pyramidal crystals; and in a fragment of the fresh-water strata about a foot in thickness, and many yards square, which was cut through in sinking a well at the south-eastern corner of the tank, the calc-spar especially, abounded in the cavities following the line of the stratum. This was the case, too, in a well which was excavated at Paidhonee, in the centre of the Native Town. Throughout the more brecciated portion of these effusions it is disseminated in small masses, or veins, or mixed up with the rock generally, and, indeed, wherever there are portions of the fresh-water strata present there is almost sure to be more or less calc-spar, though the former are essentially argillaceous; while the opposite is the case in the other parts of the igneous rock, which are not mixed up with the fresh-water strata. With the exception of a little pyrites here and there, calc-spar is the only accessory mineral worth mentioning in these effusions.

The consistence of the Volcanic Breccia varies very much: in some parts it is exceedingly hard and tough, as at Carnac and Tank Bunders, especially towards the surface, where the mass is in polygonal divisions;

out towards the interior it becomes soft. In a well which was excavated into it through the *Trappite* ridge nearly opposite Sewree, it cut like cheese, and so similar in consistence was the whole that, but for the fresh smooth section, I could not have distinguished the angular fragments. In other parts, again, where it is exposed, it is loose and sandy, but, from the presence of argil, always of sufficient consistence to keep together.

From the protean nature of these effusions, then, it is not unlikely that some of them should resemble the rock called *Laterite*, which is so widely spread throughout the Trappean District of Western India, and such is the case. It may not be uninteresting, then, to compare the two; but, before doing so, let us shortly review the opinions and descriptions that have been given respecting *Laterite*, and for this purpose I shall quote largely from Mr. Cole's interesting paper on this rock, published in the Madras Journal of Literature and Science, vol. iv. 1836, p. 105.

Characters of Laterite.—Dr. Buchanan (Gleanings of Science, May 1831), who first described and named this formation, says that "it is full of cavities and pores, and contains a very large quantity of iron, in the form of red and yellow ochres. In the mass, while excluded from the air, it is so soft that any iron instrument readily cuts it," but after exposure becomes "as hard as brick." He never observed any "animal or vegetable exuviæ" in it, but had heard of such having "been found immersed in its substance": it blackens externally on exposure, and is found universally overlying granite. Dr. Buchanan nowhere mentions its association with trappean rocks. But Dr. Christie (Mad. Jl. vol. iv. p. 468) states that "it is found resting in different situations, on granite, transition rocks, trap, and sandstone." It may be seen at Mahableshwur capping all the trappean mountains upwards of 100 feet thick, as well as I can remember, and giving them flat tops; and I am informed by Mr. N. A. Dalzell that in the cliffs on the Malabar Coast about Rutnagherry it may be seen even overlain by basalt.

Mr. B. Babington considered *Laterite* to be composed of the detritus of syenitic rock, and to be alluvial, "formed from the washings of the Ghàt mountains." He states that "the hornblende uniformly decays into a red oxide [of iron ?], and the felspar into porcelain earth"; that it forms rounded hills below the Ghàts; and, between Tellichery and Madras, he accounts for its cellular structure by the rain washing away its white parts, and leaving the red.

Dr. Voysey, who seems to have had the clearest conception on these matters of any Indian geologist with whose writings I am acquainted, made the following statement in a letter to General Cullen, dated 5th November 1820, copy of which appears in Mr. Cole's paper:—"The

indurated clay you mention is very probably the result of those muddy eruptions so common, and of such extensive occurrence, in South America. Indeed, I am convinced that the greenstone, basalt, waeké, iron clay or laterite, and the indurated clay, have all a common origin, from the insensible degrees by which they pass the one into the other; and they only differ as to the degree of pressure to which they have been subjected when under fusion."

Again he mentions (Jl. As. Soc. Bengal, Aug. 1833, p. 400), when alluding to the passage of basalt into waeké and then into iron clay, [*Laterite?*] that the latter takes place "in the space of a few yards."

Dr. Christie (*loc. cit.*) calls the laterite of Buchanan a "clay-stone conglomerate" (pp. 462 and 468), and states respecting its position in the district of Dharwar, that it is found "principally in its western parts, and on the summits of the Ghàts."

Mr. Cole states of a specimen of *Laterite* from Nellore, given him by the late Dr. Malcolmson, that "it was filled with innumerable minute pebbles of quartz, rarely larger than half the size of a pea, sometimes pellucid, generally much rounded; together with yellow and ochraceous earths." These would seem to have been the miliary contents of an amygdaloid,—whether *in situ*, or in a decomposed or altered rock, or forming foreign substances in a subsequent effusion, I cannot pretend to decide, but I should think the former.

Mr. Cole also quotes Mr. Coulthard (As. Res. vol. xviii.), whose observations appear to favour this supposition, viz. that "the iron clay" about the Sagar district, and which is easy to be met with everywhere there, "is for the most part amygdaloidal."

Lastly, Mr. Cole himself states of the "Red Hills" at Madras, in the banks (15 feet high) of the old channel, leading into what is termed the lake, that "they are composed of a dark ferruginous stone, arranged in a stratiform manner, presenting seams or partings, two or more feet asunder, parallel to each other, and nearly horizontal. Vertical fissures intersect the seams at right angles, and thus produce prismatic masses of rock." The rock is a "conglomerate," consisting of nodules of various sizes, imbedded in a "clayey paste," which is hard and tenacious: they are "water-worn," but present a "considerable angularity of surface, yet still sufficiently rounded to indicate their having undergone attrition"; in size they range from "a filbert to masses a foot or more in diameter. Their fracture exhibits the structure of a coarse-grained sandstone, or grit, of a deep chocolate or claret hue." "Small masses of white earth-like lithomarge and mica are sparingly scattered in the sandstone nodules." On ascending the hill on the side of the lake, the conglomerate disappears, and changes into the more characteristic laterite, red and cavernous, with "tortuous cavities"; still, however, containing fragments

of the sandstone, seemingly united "by the *débris* of the sandstone itself, of iron ores, and lithomargic earth." (Pp. 110 and 111, *op. cit.*)

All these descriptions then very much approach that of the Volcanic Breccia of the secondary effusions in the island of Bombay. The external surface of the hills at Sion, and the cuttings of the railway through them, show that they are composed of a red argillaceous and ferruginous base, filled with cavities, containing white or yellowish lithomargic earth, this lithomargic earth principally consisting of decomposed laumonite, or its pseudomorph in the form of white green-earth ; the masses hard superficially, and soft or sectile internally ; with more or less fragments of the fresh-water strata, *Trappite*, and amygdaloidal rocks. Hence it is not strange, if these effusions should be identical with the *Laterite*, that *Laterite* should, under certain circumstances, *contain* organic remains ; for in the former we have masses of black shale, as at the Sluices, consisting almost entirely of organic remains ; and a hundred other instances might be adduced in the second and third effusions, where the organic remains are not only in masses of shale, but entirely isolated from it, and alone in the igneous rock,—to wit, the scattered pieces of wood, &c. found in parts of the 2nd-effusion at the Sluices, and the frog-bones at Malabar Hill.

The late Captain Newbold has observed, that at Pondicherry the *Laterite* "occasionally possesses a distinctly stratified and conglomerate character, and passes into a loose coarse sandstone, imbedding silicified wood ; and at Beejpoor, on the Malabar Coast, it passes into loose sandstone, imbedding layers of lignite" : also that General Cullen had discovered "lignite and carbonized seeds in the laterite of Quilon and Travancore." (Jl. As. Soc. Bengal, vol. xiv. p. 299.) And the following description of the *Lateritic* rock which forms the upper part of the hills in the "Rajmahal Coal Formation," about 130 miles NW. of Calcutta—which would very nearly do for the red Volcanic Breccia in the island of Bombay—may be another instance of its containing organic remains. Thus, "the higher ridges of these mountains consist of scoriform masses of red earthy vesicular conglomerate (laterite), containing angular and other fragments of altered coal-measure shales, ferruginous and micaceous sandstone, imbedded in a semi-vitrified and vesicular matrix. These ridges are without any signs of stratification, except where detached masses of altered coal formation occur ; while the upper portion of their declivities, as well as all the lower and intermediate ridges, are composed either entirely of amygdaloidal trap, containing zeolites and calcedony, or altered coal-measure sandstone and shale, the latter passing into the small isolated patches of coal-measures which are found in some of the narrow valleys and ravines mentioned."—*Report of the Geological Survey of India for the Season of* 1848-49, by J. M'Clelland, Surgeon, Bengal Service, p. 45.

Thus we have *Laterite*—for such Dr. M'Clelland evidently concludes that of the Rajmahal Mountains to be—at the three points of the great triangle, formed by Madras in the south, the Rajmahal Hills in the east, and the island of Bombay in the west.

Again, we may see at Dharavee, in Bombay, the light fawn-coloured aphanitic rock, called " White Trap," and which I presume is equivalent to Dr. Voysey's wacké, decomposing, and passing, as he has described the latter, within a few yards, into a mottled white and red decomposing rock, with cellular cavities, filled with the soft greasy white clay mentioned, thus confirming what this acute observer has so clearly stated in his letter to General Cullen, viz. " that the greenstone [*trappite*], basalt, wacké, iron clay or laterite, and the indurated clay, have all a common origin," viz. volcanic.

To illustrate these *Lateritic* changes by simile, might I not state that as a stream of water passing from a clear lake to the sea may become discoloured by the kind of detritus which it takes up on its way, still remaining pure at its source, so a volcanic stream, on its way to the earth's surface, may, from the nature of the rocks through which it passes, be converted into the various forms met with in the *Laterite ?* I do not mean to assert that such effusions are in the same state now as when they were first poured forth ; for we know from every-day experience that the most compact rocks, like all other things, have but a stated time to go through their different phases ; that a re-arrangement of particles is continually taking place in them ; that some minerals are carried away, and replaced by others ; that others are carried away, and leave nothing but their empty cavities,—colour, substance, form, all is sooner or later changed and dissipated. But in the volcanic matter which has become *Laterite*, the presence of foreign material does seem to have curtailed to a certain degree its vitality, so to speak, and to have caused it to decay sooner than it otherwise would have done; and I think, when among the Trappean Rocks we do not observe the common forms of structure and colours peculiar to them both in their compact and decomposing states, we may infer the presence of this foreign material, though it is not demonstrable to our senses. Why *Laterite* should be so impregnated with iron, and the red colour so developed in it, seems not less inexplicable than that of the New Red Sandstone,—the Rothliegendes or Exeter Conglomerate of which so closely resembles the Volcanic Breccia of Bombay. Mr. Logan's hypothesis, that when the red colour has extended into other rocks the agency of " volcanic steam, gases, or fluids charged with iron," may account for their red disintegration, seems also tenable—that is, where they have not enough iron in them otherwise. Indeed, his hypothesis throughout will be found hardly less applicable to the island of Singapore than it is to that of Bombay. (Jl. As. Soc. Bengal, vol. xvi. part 1, p. 534.)

Genuine pieces of *Laterite* only differ from the rock of the hills at Sion in being more ferriferous, and in presenting a cavernous structure, composed of sinuous instead of irregular spheroidal cavities: such differences bearing no comparison with those which exist between the red brecciated hills at Sion and the black jaspideous hills of Antop and Sewree, though they are both parts of the same formation.

Thus the subsequent effusions in Bombay would appear to be identical in origin, and almost so in structure and composition, with the *Laterite*, though the latter has been stated not to come further north than the Bancote River, which is 60 miles south of Bombay. And it should be remembered that this breccia is not confined to the island of Bombay—that, indeed, we only have a specimen of it here; but that it forms the principal part of the mountains in Salsette, and may be seen at the northern extremity of that island, viz. at Ghora Bunder, which is 18 miles from Bombay, containing there, as in Bombay, large pieces of aqueous strata, apparently identical with those of the Fresh-water Formation in Bombay. How far further north or south it may extend is not yet known; but if the masses of aqueous strata in it be really identical with the fresh-water ones of Bombay, their existence at Ghora Bunder not only proves that the Volcanic Breccia extends so far, but that the lake or river in which these fresh-water strata were deposited must have also extended this distance.

There is one fact more which I forgot to mention, and which is still further confirmatory of Dr. Voysey's opinion respecting the common origin of greenstone, basalt, wacké, and laterite, viz. that much of the third effusion or Volcanic Breccia, which I think we must now regard as *Lateritic*, if not genuine *Laterite*, is in the state of kaolin, and when pieces of it are well washed with a brush in water, they present in like manner the angular parts of the undecomposed grains, possessing the same greenish tint and appearance as those of the fine-grained *Trappite* of the *Trappito-basaltic* tract.*

Having now gone over the *Fresh-water Formation;* the first of the secondary trappean effusions, or *Trappito-basaltic;* the second of these effusions, viz. the *Trappito-amygdaloidal*, as it may be so termed; and the third or *Volcanic Breccia*, together with the *dikes* of the same, which constitute the 4th-effusion,—indeed all the older formations,—let us now go to the modern ones, viz. those of the Pliocene Age, the geological age of the others being as yet undeterminable.

This modern series merely consists of the *Clay* which fills up the central or lagoonal depression of the island, and the *Shell-concrete*† which overlies it in Back Bay, in the neighbourhood of Mahim, and at Sewree.

* For further remarks on *Laterite*, see my "Summary of the Geology of India," further on.

† Dr. Buist's name for this formation.

Clay.—This is a stiff plastic deposit, of a fine uniform structure, not effervescing with acids: the colour is brown above, blue below, and then yellowish, where it rests upon or mingles with the decomposing igneous rock, or the remains of the fresh-water strata. Its thickness of course varies with the irregularities of the igneous rock beneath, but it diminishes also gradually towards the sea, or where it passes under the *Shell-concrete.* Thus at the southern part of the island, within three quarters of a mile of Back Bay, it is 10 feet thick; after this it diminishes in thickness towards the sea in Back Bay, and 600 yards from the latter, where it is yet overlaid by the *Shell-concrete,* it is only 4½ feet thick, and of a blue colour: still nearer the sea it seems to disappear altogether, for it was not met with in a well 20 feet deep in the Girgaum Road, about 300 yards from it.

The same thinning out probably takes place under the *Shell-concrete* of Mahim, at the northern end of the island; but there I have not had the same opportunity of examining it.

This clay is also met with at Sewree, where Dr. Buist, who has paid much attention to the formation, pointed it out to me. There the sea is exposing it, and scarping the *Shell-concrete* which overlies it, by which one might infer that this portion of the island was undergoing elevation.

Like most argillaceous deposits, it contains very few organic remains: the shells are almost all confined to the *concrete* which overlaps it—still here and there it does present a few scattered ones. At Sewree, at Mahim, and under the *concrete* at Back Bay, it contains a good deal of wood, probably the stumps of mangrove trees, which originally grew in it. This wood seems to be chiefly confined to the parts mentioned, and presents a number of calcareous tubes, which are straight or undulous, and from a half to three quarters of an inch in diameter. They are more or less filled with calcareous infiltrations, and originally were formed round the borings of some pholadine animal. The wood itself is in a spongy expanded state, and contracts remarkably on drying; assuming a compact solid form, which breaks with a smooth or resinous fracture, and presents a semi-carbonized appearance of a deep black brown colour, very much like coal. It burns, however, more like wood, readily, and with a bright flame, emitting a great deal of smoke, and woody odour; also leaving a white ash. In different parts of the lower clay, oyster-shells are found, adhering to boulders and loose stones, the same as those now found on the shores. Pholadine tubes, infiltrated with calcareous matter, also abound throughout the clay, and here and there the remains of crab-shells, &c. I have not met with any remains of man, or any other animals, in the clay; and no pottery, or anything resembling an artificial construction, I believe, has been found in it.

There is a feature of this *Clay*, however, which is very remarkable, viz. the *Kunkur formation*. This, which consists of concretionary limestone, occurs massive or scattered throughout the *Clay* in small isolated portions. In its massive state it is found in large boulders, or in continuous tracts, reposing on the fresh-water strata or igneous rock beneath, and in this state is compact and cavernous, enclosing portions of the *Clay* in its cavities, &c. in which it has been formed, or as a conglomerate with sandy or gravelly detritus from the igneous rocks, and the remains of small shells, assimilating it to the sandy beaches. Those portions which are scattered throughout the *Clay* are more or less round, like *Septaria*; very uniform in structure, and some so pure that they wholly dissolve in nitric acid. They are generally of a blue colour, but sometimes quite white, and identical with chalk. Like *Septaria*, also, they are irregular, and almost invariably envelope the remains of some organic matter, such as pieces of reeds, wood, the remnants of crab-shells, &c. &c. which are very frequently removed, and leave nothing but their moulds in the centre of the concretions. This substance also accumulates in the interior of shells, and almost always fills the cavities of pholadine tubes which have been formed in the *Clay*. It does not always, however, envelope organic remains, but may be seen appended to them in a globular form—to the pincher of a crab-claw, for instance. Occasionally it may be seen in a vertical section of the *Clay*, in the state of a number of isolated particles or concretionary nuclei round a piece of wood, as if in process of forming a nodule, not by successive layers, but by the increase of substance round different centres. It will hardly be asked where this lime comes from, when we have seen so much of it in the igneous rocks, and in the laumonite filling their cellular cavities, which mineral contains twelve per cent. of lime.

Shell-concrete.—Lastly, we come to the *Shell-concrete*, which is chiefly found on the northern and southern sides of the island, and not on the western or eastern sides: not on the western, because the whole is composed of black basaltic rocks, extending probably for a long distance into the sea; and not on the eastern side, because there are no waves to form it, since wave-action, combined with the presence of sand, &c. is of course absolutely necessary for this purpose. Hence it is at the mouths of estuaries such as these, emptying themselves into the sea on the north and south of the island of Bombay, that we chiefly find this formation: the sand is brought down by them, and, when flowing into the sea, is there, with the shells, turned back by the waves upon that part of the shore which by its form and position is best adapted to receive and retain it. Thus we see the chief accumulations of this material in Back Bay and at Mahim, the former on the north, the latter on the south side of the island; and at each of these places presenting concavities

to the NW. and SW. respectively, from the inner side of the island being so much longer than the outside. At Sewree, also, which presents a short shore with a southerly aspect, there is a small accumulation of this kind, which seems to have been thrown up by the swell of the south-west monsoon, as it falls almost point-blank upon this bit of shore on its way up the harbour. Also, in the centre of the island, there was a patch of it six feet thick, called Phipps' Oart, from which the railroad contractors obtained sand for the surface of the railroad. At first it appears thoroughly isolated and difficult to account for, but when we observe a breach in the eastern and western ridges of the island immediately opposite it, and see the remains of shells and sand scattered over the surface of the *Clay* in a line between these two breaches, we no longer hesitate in applying the same reasons for its formation here that we have in other places, viz. that through the breach in the eastern ridge came sand from the harbour, and through the breach in the western ridge, viz. that at the Vellard, came the waves from the sea which ponded it back, and formed the mound mentioned. At that time the island must have been divided in two parts, and the cause of this being discontinued would seem to be sought for in its subsequent elevation; but the summit of the mound of sand and shells called Phipps' Oart not being more than about nine feet above the sea at high-water, and the latter kept from overflowing a great part of the "Flats" by embankments, the drying up of the island would seem to be more from the accumulation of detritus brought down from the hills on the mainland than from anything else.

At Mahim, the tract of *Shell-concrete* is two miles and a half long, and extends 1,000 yards inland, and at Back Bay it is two miles and three quarters long, and extends about 600 yards inland, forming segments of large circles at each place. The thickest part of the latter appears to be its western end, where the south-west monsoon swell beats most upon it, for about its centre, viz. 300 yards from the sea, it is 20 feet thick, 18 feet on the Esplanade opposite the Sanitarium, and towards the southern extremity of the Esplanade 15 feet thick, where it rests on the igneous rocks, and large spheroidal masses of coral (*Cellastrea*, Bl.).

With the composition of these beach-accumulations we are perfectly acquainted from the wells that have been dug through them. As before stated, the *Clay* thins outwards under them, and they, in return, inland, thin out upon the *Clay*, but have of course always that ridge above the *Clay* which is common to such formations.

Not having had the opportunities of examining that of Mahim which I have of that in Back Bay, though both are probably alike, I must take my description from the latter. It is composed of beds of yellow sand and small shells dipping at an angle of about 15° towards

the west, or towards Back Bay, and resting on the clay, or igneous rocks of the locality, according to that portion of it which is nearest the sea, and *vice versâ*. The sand is chiefly confined to the upper part, but a few feet down begins to present beds of small sea-shells, for the most part entire. These increase in quantity, and take the place of the sand, while they become cemented together by calcareous matter, and form the concrete material from which this formation has derived its name. The shells for the most part chiefly consist of small bivalves, *Cardium* and *Tellina;* also of small univalves, *Turbo*, *Cerithium*, and *Nerita;* a large *Trochus* and *Turritella*, and a thin pearly *Placuna;* in short, species of all the genera which are now found on that part of this old beach which is in process of formation. As before stated, these materials rest on the *Clay* or the igneous rock, and probably in some places on the lacustrine strata, where the latter have not been carried away by denudation. I have frequently looked among the portions which have been quarried for bones of the human skeleton, and for remnants of pottery, but have never met with either.

Drift-sand Bank.—Extending from Mahim Fort down by the beach there is a ridge of sand sloping inland which has served a long time for a cemetery, and on which, besides grave-mounds, there are a number of cocoanut trees, averaging, as far as I can make out, about fifty years old. This bank during the monsoon of 1854 became scarped perpendicularly for about fourteen feet, and thus were exposed innumerable human skeletons lying parallel with the beach and about three tiers deep. The bones were so fragile that they could hardly be taken out of their position without breaking. From the thickness of the bank and the successive layers of skeletons, some of which were in walled graves, and many had Mussulman (?) head-stones with sculptured ornaments, but no characters, this must have been the cemetery of the village of Mahim for ages past. Here, just after the monsoon mentioned, might be seen the skeletons of generations piled one upon another with those of their families who had been cut off in their infancy or childhood distinguished by their different lengths, entire and bleached, though on the verge of mixing with their parent element.

This concludes all that I have to offer on the Geology of the Island of Bombay, with the exception of the following "practical observations."

Building Materials.—The most durable stone is that which caps the *Trappito-basaltic* tract throughout, but it is very tough; the next, which lies below it, at Nowrojee Hill, &c. is less compact ; this is much more cleavable, and is found all along the eastern ridge. After this comes a more earthy form of *Trappite*, which is found at the base of Nowrojee Hill Quarry; also the so-called "white trap" *(aphanite)* at Dharavee,

a modification of which (*spilite*) is again met with on the eastern side of the "Flats" about the middle of the island, near the railroad. It is with this that the principal part of the stone-work of the railway is built; and although not so durable as any of the foregoing, is sufficiently so for economical purposes. The Volcanic Breccia, in the neighbourhood of Sion, also furnishes a rough stone, which, from its soft argillaceous nature when fresh hewn, and subsequent hardening, serves very well for troughs, for which it was formerly much used. Last of all, and least durable and expensive, is the *Shell-concrete*.

Lime.—The concretionary limestone called kunkur, lying at the bottom of the clay in the "Flats" in detached masses, or in continuous tracts, together with the nodular forms in the clay itself, furnishes an abundance of lime, the purest coming from the nodules. Recent shells, however, are collected and burnt for this purpose, from their furnishing a still purer material.

Sand.—This comes from the *Shell-concrete* formation, and, being chiefly composed of the detritus of small shells and argillaceous matter from the disintegrated trappean rocks and fresh-water strata, hardly contains any siliceous sand; hence it makes very bad mortar: much of it being taken from the sea-shore also, it is more or less impregnated with salt, which after a while makes the mortar crumble, and where this is covered with plaster, the latter to fall off. It has always appeared to me a great defect in the plastering of this part of India, not to mix hair, or tow, or straw, with the material. All who have anything to do with new buildings in Bombay must have seen the plaster frequently falling off from the circumstances I have mentioned, and that no secondary plaster ever stays long on such surfaces. Hence the necessity of taking sand from parts which have been long exposed to the percolation of fresh water, and which is free from salt, and mixing some fibrous material with the plaster, to make both it and the mortar more durable. It is no light matter this in the construction of a building, for without it the expense of repairs will ever be as it is now, endless, and the appearance of the buildings squalid and disgraceful, although an unlimited amount of money may be expended upon them annually.

Wells.—The only rule that can be laid down for digging wells is that the *Trappito-basaltic* tract must be pierced through to the fresh-water strata, and even then there may be no water: for a foot or two below this there may be an intrusion of the igneous rock, and then this must be pierced until arriving at another layer of the fresh-water strata, and so on until water is reached. Sometimes the meeting with a rent in boring through the *Trappito-basaltic* tract, or a dike of the subsequent igneous effusion, may, by communicating with water below, yield the latter before it could otherwise be expected; but from the manner in

which the fresh-water strata and superincumbent *Trappito-basaltic* tract have been broken up and intruded throughout the island, by the subsequent igneous effusions, it is plain that none of these springs can be inexhaustible. Last year proved it, for nearly all the wells were dry from the scarcity of rain the year before. There is another fact, viz. that many of these rents and dikes let in a spring of brackish water: this is particularly the case in the neighbourhood of Byculla. Experience there has often exemplified the proverb, that "you may go further and fare worse." This was the case in a tank enlarged by Sir Jamsetjee Jejeebhoy on the north side of the Grant College. In sinking a well at the south-western corner of Baboola Tank last year, too, the workmen came upon a thin line of the fresh-water strata, accompanied by an oozing of saltish water, and of course were ordered to cease further operations directly. How it comes to pass that this water should be brackish I can only conjecture; for it is not owing to the presence of the white rock (or subsequent effusions), since at Mazagon there is a well 60 feet deep, entirely excavated in the latter, and yet yielding excellent water. Again, the tank mentioned, which was enlarged by Sir Jamsetjee Jejeebhoy, does not extend into the white rock, and yet the water in it is so brackish that it is hardly fit for anything but watering the roads. Two tanks or wells shall be found within a few yards of each other, the one containing drinkable, the other undrinkable water. As I have before stated, all that I can offer in explanation of this is conjectural, viz. that when the *Trappito-basaltic* tract and aqueous strata were broken up by the subsequent effusions, the sea-water may have run into the crevices, and there, becoming vapourized, have left its salt behind it; or, otherwise, the sea at the present time may be sucked up by these rents and dikes, which by their intercommunication may carry it here and there throughout that part part of the island where the brackish wells are most common. If the former opinion were entertainable, then the constant emptying of these wells should at last make them yield fresh water: but this is not the case, for they are emptied yearly for watering the gardens, and still continue to be salt. At the same time, those which are never emptied are decidedly the most brackish. If, on the other hand, the latter be the explanation, then there is no remedy for it.

Coal.—The quantities of this mineral found at the cutting of the Sluices, where the fresh-water strata containing it have only been excavated for a few cubic yards, is very trifling, although the fossilised wood and *débris* of vegetable remains are very considerable. The nature of the coal is described at page 131. It hardly ever occurs in grains larger than a pea, and for the most part in layers over compressed flat long leaves or stems; although the whole of this part of the fresh-water

deposit is highly carboniferous. At the same time it should be remembered that in the only place where these strata have been exposed they have been broken up by the intrusion of the igneous rock, and that although the wood and other vegetable remains in them here are principally replaced by argil, yet that they may be more coal-bearing in other parts. A further examination, then, of this part of the fresh-water formation in different localities would be highly interesting, if, even after all, it should not prove useful.

List of Rock-Specimens, Minerals, and Fossils, from the Island of Bombay, illustrative of the foregoing Paper.

Presented to the Bombay Asiatic Society by Dr. LEITH, and the Author.

[Those marked with a † were presented by the former, and those with an * by the latter; the † and * together denote that specimens of the same object have been presented by both.]

No.

1 * Tough bluish-gray basaltic *Trappite,* containing olivine, and grains of magnetic iron ore, from the upper part of Nowrojee Hill.

2 * Fissile and more compact, from ditto lower down.

3 * Fine-grained crystalline *Trappite,* from the ridge extending northwards from Jackaryah's Bunder.

4 * Mottled blue and brownish grey *Trappite,* from the ridge extending northwards from Khandlee Battery.

5 * Orbicular or botryoidal *Trappite,* from the same ridge a little south of Tank Bunder.

6 * Tough black fine granular *Basalt,* from hexagonal prisms at Worlee.

7 * Fissile black or dark fine *Basalt,* from beneath the surface Malabar Hill.

8 * Tubes, formed of crystalline quartz, from bottom of *Basalt* at Mama Hajanee.

FRESH-WATER STRATA.

9 * Portions of the upper part of the fresh-water strata, from different localities: the light brown from the tank north of the Horticultural Gardens, and upper part of Baboola Tank; the blue from the well (see p. 152) in Baboola Tank; the brown from the *spilite* on the eastern side of the Flats, nearly opposite Parell; the greenish or bluish grey or brown from the Sluices; the blue and brown from a well on Malabar Hill.

10 * Portions of the stratum composed of the casts of *Cyprides,* from the northern side of the Breach at the Sluices; ditto from the northern end of Chinchpoogly ridge.

11 * Greenish grey or brown shale, from the Sluices.

12 * Ditto, with interlaminated black shale, from ditto; also from a well on Malabar Hill.

13 * Black bituminous shale, from ditto, and from a well on Malabar Hill.

14 * Chertified aqueous strata, bent.

15 * Basaltified ditto, with organic impressions.

16 * Jaspidified ribboned ditto.

17 * Chertified portion of *Cyprides* stratum.

18 * Ditto jaspideous ditto.

19 * Coal from the Sluices.

20 * Mineral resin from ditto.

Vegetable Remains.

No. *Roots.*

21 † Cormiform, conical roots? from the Sluices (several specimens and sections), (p. 131).

22 † Cormiform, globular, from the Sluices (several specimens and sections).

Stems.

23 *† Cylindrical (two specimens), (p. 132).

24 *† Wood, dycotyledonous, several specimens of, large and small,—and monocotyledonous (bamboo?) (p. 133).

25 *† Ditto with bark, two specimens (p. 133).

26 *† Fungoid or adventitious woody excrescences? in the bark (p. 133).

Leaves.

27 * Oval, small,—like leaflets of an Acacia (p. 134).

28 *† Long, flat,—like bulrushes, large and small (p. 134).

29 † Scaly, long leaf, or surface of a stem? (p. 134).

30 † Lanceolate leaves, like those of bamboo (p. 134), also cordate leaves.

31 † Impression of *Cyperus?*

Seeds.

32 *† Small, flat, lenticular capsule, with a ring of seeds arranged round the internal margin (p. 135).

33 † Seed-like *Artabotrys odoratissima* (p. 135).

34 † Siliquose seed-pod (p. 135), with sections (several specimens).

35 † Ditto (p. 135).

Animal Remains.

36 † *Cypris semi-marginata* (H. J. C.), (p. 136).

37 * *Cypris cylindrica* (Sow.), (p. 137).

38 * Another species, *C.* ——— ? (p. 137).

39 † *Lymnadia?*

40 † Elytra of a small coleopterous insect, right wing (p. 138).

41 † Impressions of fresh-water shells, *Melania?*

42 * Do. do. do. *Paludina?*

43 † Do. do. do. *Pupa?*

44 *Rana pusilla* (Owen), skeletons of, several specimens (p. 138).

45 Do. do. do. large and small. (In these specimens, though one skeleton appears larger than the other, the thigh bones are all of the same length.)

46 Do. do. do. in different layers an inch apart (two specimens), (p. 140).

47 * Do. do. do. on a layer of *Cyprides.*

48 * Do. do. do. bones of, scattered in intruded igneous matter (p. 140).

49 † *Testudo Leithii* (H. J. C.).—*a* carapace and plastron; *b* ditto with head; *c* head alone; *d* left half of the carapace and plastron; *e* fragment of ditto; *f* ventral part of pelvis and sternum opposite; *g* fragment of carapace, with margino-collar scales; *h* fragments of marginal scales; *i* ditto; *k* ditto; *l* right two-thirds of carapace and plastron.

2nd-Effusion.

50 * Greenish-blue and black *Trappite,* from Nowrojee Hill, below the line of aqueous strata.

No.
51 * Amygdaloidal *Trappite*, from Baboola Tank; cells filled with crystals of laumonite.
52 * Laumonite and dog's-tooth calc-spar, from a geode in ditto.
53 * Rhomboidal calc-spar in mass, from ditto ditto.
54 * Ditto ditto following a line of aqueous strata; from do. do. (p. 152).
55 * Ditto ditto in a minute imbricated form, separate, and covering dog's-tooth crystals, from ditto ditto.
56 * Prehnite from ditto ditto.
57 * Amygdaloidal *Trappite*, from a tank north of the Horticultural Gardens.
58 * Black fine-grained crystalline *Trappite*, from Baboola Tank.
59 * Compact blue amygdaloidal *Trappite* from Baboola Tank; cells elongated, and filled with massive laumonite.
60 * Greenish-grey amygdaloidal *Trappite* cells, filled with green-earth, from the neighbourhood of the house called Lowjee Castle.
61 * Ditto decomposing cells, filled with quartz crystals, from upper side of dike in Chinchpoogly ridge.
62 * Hyalin and amethyst quartz crystals, from crushed geode in ditto.
63 * Amygdaloid, with brown earthy base, and cells filled with quartz crystals, from neighbourhood of Sindu Para.
64 * Brown *aphanite*, the so-called white trap, from Dharavee.
65 * Ditto amygdaloidal, from ditto; cells filled with fine white clay-earth (decomposed green-earth or laumonite), (p. 147).
66 * The same decomposing into a mottled red and white material, like *Laterite*, of a granulo-plastic nature (p. 156).
67 * More earthy *aphanite*, spilitic, with fragments of organic remains, and calc-spar, from the eastern side of the Flats opposite Parell. Forms a good stone for building, and is easily hewn.
68 * Blue *spilite* (aphanite and calc-spar), with disseminated calc-spar, from ditto.
69 * Brown ditto, with calc-spar in small masses (amygdaloidal), from ditto.
70 * Brown ditto, with calc-spar in veins, from ditto.
71 * Unsymmetrical, compressed, lenticular crystals of calc-spar, standing on their edges in a geode of ditto, from ditto.
72 * Blue *spilite*, with small crystals of calc-spar, passing downwards into *Trappite*, from ditto.
73 * Fine blue clay *aphanite*, from a well on Malabar Hill.
74 * Coarse *aphanite*, from ditto ditto.
75 * Brecciated *aphanite*, from ditto.
76 * Coarse *aphanite*, intruding fresh-water strata, from the eastern side of the Flats.
77 * *Aphanite*, bearing fragments of vegetable remains, from ditto.
78 * Ditto black ditto, from a well on Malabar Hill.
79 * Ditto bituminous ditto, from the Sluices.

3rd-Effusion.

80 * Coarse Volcanic Breccia, from the neighbourhood of Tank Bunder.
81 * Blue breccia, with white fragments, from a well on Malabar Hill: *b* ditto from Sion; *c* ditto brown from ditto; *d* ditto red from ditto; *e* ditto white and red decomposing; *f* ditto red compact.
82 * Ditto black jaspideous from Antop Hill.
83 * Ditto jaspideous, black, from Sewree.
84 * Blue breccia, passing into red clay, from Sewree.
85 † Ditto, containing a large fragment of large-grained diorite, near the village of Wadalla (p. 150).

No.

86 * Blue breccia, containing amygdaloid *Trappite; a* ditto containing amygdaloid trappite or aphanite, from ditto and Sewree.

87 Ditto, containing portions of aqueous strata.

88 * White amygdaloid *aphanite;* cells very much elongated, and filled with calcedony or quartz crystallized, from Chinchpoogly ridge.

89 Geode from ditto, containing crystals of quartz and amethyst.

90 Ditto from ditto, containing agate.

4TH-EFFUSION.

91 * Portion of amygdaloid *aphanite*, from the dike at Sewree; cells containing fine white clay-earth.

GHORA BUNDER, IN SALSETTE.

92 * Specimens of amygdaloid *aphanite*, and volcanic breccia; also specimens of aqueous strata from the latter.

MARINE FORMATION.

93 * Blue *clay* of the "Flats."

94 * Massive kunkur, from lower part of ditto.

95 * Small kunkur-conglomerate, resembling transformed sea-beach, from ditto ditto.

96 * Nodular kunkur, from ditto.

97 * Charred wood, from ditto.

98 * Infiltrated pholadine tubes, from ditto.

99 * *Shell-concrete,* coarse.

100 * *Shell-concrete,* fine.

101 * Shells from ditto.

102 * Spheroidal masses of calcareous coral (*Cellastrea,* Bl.) beneath ditto, Esplanade.

EXPLANATION OF THE MAP AND PLATES.

MAP.

The dotted portion in this Map is intended for the *Shell-concrete;* the white tract for the *Clay;* the crosses for the *Volcanic Breccia;* the broken lines running north and south for *Amygdaloid;* the continuous lines running east and west for the *Trappito-basaltic* tract; and the wavy parallel lines for the *Fresh-water Formation.*

Fig. 1.—Line intended to represent the site of Bombay as it was when covered by Fresh Water.
Fig. 2.—Transverse Section of the Island as it now is.
Fig. 3.—Sectional Diagram, showing the relative position of the different Sedimentary and Volcanic Formations.

PLATE VII.

Fig. 1.—Cormiform root of aquatic plant? natural size.
a Upper end, truncated.
b Lower end, broken.
Fig. 2.—Globular root of aquatic plant? natural size.
a Lateral view.
b Upper end, showing lines of petiolations?

Fig. 3.—Lateral view of a portion of a stem, natural size.
a Lower end, showing lines of petiolations?

Plate VIII.

Fig. 4.—Oval leaf, natural size.
Fig. 5.—Round leaf, natural size.
Fig. 6.—Compressed stem or leaf of aquatic plant, with root, natural size.
a Magnified view of longitudinal striæ on its surface.
Fig. 7.—Scaly impression of leaf or stem, natural size.
a Two scales, well preserved.
Fig. 8.—Form of the end of a flat, long leaf, which is very common, natural size.
Fig. 9.—Impressions of leaves, like those of bamboo, natural size.
Fig. 10.—Impression of a cyperaceous plant? natural size.

Plate IX.

Fig. 11.—Small lenticular seed, magnified.
a Natural size.
Fig. 12.—Oval, compressed seed, with apparently *ruminate* albumen, magnified.
a Natural size.
Fig. 13.—Seed-pod, broken off at one end, natural size.
Fig. 14.—Seed-pod, natural size.
Fig. 15.—*Cypris semi-marginata.*
Fig. 16.—*C. cylindrica.*
Fig. 17.—*C.* ———— ?
Figs. 18, 19, 20.—Valves of recent *Cyprides,* from the fresh-water deposits of Bombay.
Fig. 21.—Elytra of coleopterous insect, magnified.
Fig. 22.—Cast of shell, natural size.

Plate X.

Testudo Leithii.—Carapace, and upper part of head of, natural size. *a* Point of tail.

Plate XI.

Testudo Leithii.—Plastron, and inferior aspect of lower jaw of, natural size. *a* Impressions of posterior extremities. *b b* Union of pelvic bones with posterior part of sternum. *c* Point of tail.

Geology of the Island of Bombay. By Dr. G. Buist.*

Read April 1851.

Description of the Island.

The island of Bombay is one of a multitude on the north-western shore of Hindoostan, which, varying from a few yards to above a hundred square miles in area, fringe the Malabar Coast from lat. 9° to lat. 20° N., on a narrow examination seeming like fragments broken from the mainland during the many upheavals and depressions to which it has from time to time been subjected; several of these movements having obviously occurred at a comparatively recent period, geologically considered.

2. The Bombay Group, between lat. 19° and 20°, consists of fifteen or twenty islands in all; 1, the island of Bassein, about thirty miles to the northward of that which gives the cluster its name; 2, of Dravee; and 3, of Versova, just off the shore of Salsette; 4, of Salsette, by much the largest of them all; 5, Trombay, conspicuous for the mountain called Neat's Tongue, from the singular resemblance it bears to the tongue of an ox, and which attains the altitude of 1,000 feet; 6, Bombay itself, now on the northward united to Trombay and Salsette, as these are united to each other by bridges and embankments, and to the southward to 7, Old Woman's Island, and 8, Colaba; 9, Elephanta; 10 Butcher's; and 11, Gibbet Island; 12, Caranjah; and 13, Henery; and 14, Kenery; with little rocks and islets of lesser note and name.

3. Bombay, including the large and little Colabas, is the only island of the group I have been able to examine with tolerable care, and it is the only one I have attempted to describe somewhat minutely, though not so much so as it ought to have been. I have traversed most of the other islands, some of them repeatedly; they seem all characterised by the same geological features, and I have introduced into the description of Bombay notices of their rocks, and of those on a part of the adjoining mainland, in so far as I have had the means of examining them.

4. The principal rocks throughout this group of islands are volcanic, but there are probably a greater variety of trap rocks to be found on the

* Reprinted from the Transactions of the Bombay Geographical Society, vol. x. p. 167.

island of Bombay itself than on any similar area anywhere ; the traps are interstratified by Neptunian rocks, chiefly of fresh-water origin, and covered over with marine alluvium of three or four different ages and formations.

5. The islands are separated by narrow creeks from each other (one of the most beautiful of which is that which forms Bombay Harbour), often contracting to a few scores of yards in width, dry at half tide, and widening and deepening as they approach the sea. The Tanna and Panwell rivers discharge, during the rainy season, vast torrents into these, deepening and scouring them. Throughout the fair seasons, scarcely any water reaches them from the interior, and, unless where a strong tidal current prevails, most of them are in process of silting up. The back water occasioned by the railway embankment and Mahim Causeway will, in all likelihood, speedily unite the islands of Bombay and Salsette into one. There are extensive spaces round the greater part of the margins of all these islands below high-water mark, and which are flooded during spring tides in all of them save Bombay, where the water has been shut out by embankment, and there are spaces still more extensive from 3 to 12 feet above the level of the sea, which must at no distant date have been submerged. The islands for the most part rise into round, or nearly flat-topped hills, varying from 100 to 300 feet in height—in one instance attaining the elevation of 1,000—generally presenting a steep, sometimes a mural precipice on one side, with fine belts of cocoanut trees around the shore, affording an infinite diversity of woodland, mountain, lake, and river scenery everywhere ; the creeks, assuming the aspect of lakes, rivers, or bays, according as they are viewed. The Bombay islands are, I should think, scarcely surpassed in picturesqueness and beauty anywhere in the world.

6. The island of Bombay, viewing it without relation to the two Colabas, with which it is artificially connected, is in the form of an irregular oval, throwing out a long projection from one extremity, forming Malabar Hill and Point. The two islands of Large and Little Colaba (Old Woman's Island), now united to each other and to Bombay itself, stretch out nearly parallel to Malabar Hill, but extend much more to seaward, the two promontories terminating at Malabar Point on the north-west, and at the Lighthouse on the south, including Back Bay between them. From the Lighthouse to Sion, on the eastern, or harbour side, the distance is about fifteen miles, and about twelve from Malabar Point to Mahim, on the western side of the island, which is about five miles across from Mazagon to Mahaluximee, where it is widest. It contains in all an area of about twenty square miles, on which there is a population of close on half a million.

Basalt from Malabar Point to Mahaluximee, and so by Bandora to Bassein.

7. *From Malabar Point* to Mahaluximee* is a fine bold ridge of black basalt nearly three miles in length, and about half a mile across, called Malabar Hill, maintaining for some distance an elevation of close on 200 feet above the sea. The ridge terminates in a precipice,† near the extremity of which stands one of the residences of the Governor, and it continues precipitous for a couple of miles on the eastern, or Back Bay side: just under the highest part of the ridge the rock is tumbled about in huge masses, great irregular pillars partly buttressing the cliff, partly lying in gigantic ruins at its base. Along the Back Bay shore a considerable bed of stratified rock makes its appearance;‡—on the seaward side the hill slopes down somewhat gradually; from opposite the Back Bay beach and Love Grove there are two independent ridges, near the Parsee "Towers of Silence," of unequal elevation, the lower being that by the north-western shore. They are divided from each other by a deep dell of some half mile in length, and 300 or 400 feet across.

8. The Malabar Hill ridge is partly broken across near Tankerville, by the deep hollow through which the public road passes, but there seems no change in the character of the rock on to Mahaluximee, where the basalt becomes tabular, and looks from a distance like stratified rock; it here sinks under the level of the sea, and seems intersected for a few yards by a mass of strata set nearly on edge, stretching into the Bay opposite the residence of Sir Jamsetjee Jejeebhoy. From this for about half a mile the rock is concealed by the velard—by the silt of the Flats on the one side, and the gravel of the sea on the other, but appears to be the same as before. It reappears in the beautiful little eminences of Ram Hill, Love Grove, and the adjoining high grounds, and is once more partially interrupted by stratified rock, abounding in organic remains at the Sluices, and again reappears just beyond, forming the wooded ridge of Worlee Hill. At Worlee village it disappears under the sand and alluvium, but there is no evidence of its being interrupted;

* See Section I., at the end.

† Mr Clarke estimates (Geol. Trans. Jan. 1847) the thickness of the stratum of basalt above the trap at about 70 feet; so far as Malabar and Tardeo Hills are concerned it seems without the mark—it is nearly correct at the Love Grove section, to which he more particularly refers.

‡ A mass of diorite or greenstone, totally unlike the basalt of which the rest of the ridge consists, was this season (1856) cut through on digging a well in a Native garden close by the entrance to the Government house grounds, at the further end of the village of Walkeshwur. At the depth of 30 feet a pale grey alluvial stratum of earthy looking rock was met with, exactly like that traversing Nowrojee Hill.—G. B., Aug. 1856.

it rises suddenly across the creek at the Portuguese promontory of Senora de Monte of Bandora, and continues as a great sea-wall all along shore, for ten or fifteen miles at least.

9. At the old castle on the south-eastern extremity of the little island of Versova, it is columnar. Again, on the west side of the island, facing Salsette, it is highly porphyritic, the felspar crystals imbedded being nearly half an inch each way; they are of a dirty yellow colour,—the rock itself is brownish black. Just round the promontory, to seaward, a fine picturesque group of columns rises from high-water mark. They are of a pinkish brown with a tint of red, as if moss-grown, or weather-worn; they ring like metal when struck. When broken, it appears that this is the natural colour of the rock, which, though heavy and hard, is open and porous,—a hand specimen much more resembling sandstone than trap. Further north it turns black again, and narrows to a pretty uniform well-formed dike, from 50 to 100 feet across, rising here and there into picturesque little hills or islands, and appearing everywhere for ages to have walled off the sea from a low and easily abraded coast. At Bassein it runs into somewhat bolder cliffs, and presents several beautiful groups of columns, black and compact, like the rock at Malabar Hill;—beyond this I have not had the means of examining it. The basalt barrier seems broken through only by the creek opening into Bombay Harbour. Stretching southward and eastward from Malabar Point it reappears at Alibaugh on the coast, sixteen miles to the southward, and seems for a long distance to protect the shore. I have traced it for seventy miles, from Bassein to Alibaugh: beyond this, again, my knowledge is at fault.

10. From the basalt ridge just described, eastward, for the space of two miles, the island is almost perfectly flat, rising at the highest some 8 or 10 feet above the level of the sea: much of it would be submerged at high tides were the sea not artificially shut out.

Trap, mostly Greenstone, from the Prongs, through Colaba, the Fort, Mazagon, etc. on to Sion.

11. A mass of trap, mostly greenstone, extends from the Lighthouse, at the extreme south-eastern end of Colaba, on all the way to Sion, on the eastern side of the island, facing the harbour: instead of forming one continuous ridge, like the basalt from Malabar Point to Mahaluximee, it often sinks down to the level of the sea, where it is covered over with alluvium, and is only traceable in wells, quarries, and other excavations: it sometimes rises into knolls, sometimes into beautifully picturesque little hills, of above 100 feet in elevation. It varies as much in quality as in aspect, presenting us occasionally with a nearly black amygdaloidal greenstone,—next Parell, to the south of this fine

soft, pale-blue earthy trap—with every variety of tuffa, amygdaloid, and compact greenstone, that can be imagined.

12. *Details.*—The highest part of Colaba is that on which the lighthouse is built—it is about 55 feet above the mean level of the tide. From this the surface descends on both sides to the sea, sloping gradually to the NE., in a line with the axis of the island. The trap here, as everywhere along our shores, is covered, at from 6 to 10 feet above high-water mark, with sea gravel, loose or cemented. For upwards of a mile to the south-east, east, and westward, filling up a large space on the harbour side, and the bulk of the area of Back Bay, the trap is covered by the tide. The line of junction betwixt the basalt of Malabar Hill and the greenstone of Back Bay is lost under water: it is probable, from the aspect of the cliff, and the depth of water near its base, that a mass of softish stratified rock, through which the principal channel has been grooved, interposes itself betwixt them all the way along. Opposite the Marine Lines there is a large mass of well-formed columns of basalt, which just show themselves above low water,—apparently beneath the fresh-water strata at the base of Malabar Hill,—becoming tuffaceous near the line of junction, as if erupted from beneath after the deposit of the alluvium now above them.

13. About a mile and a half from the Lighthouse, towards the Fort, near the site of the Cabool Church, a mass of stratified rock makes its appearance on the harbour side of the island, showing itself along the sea shore near the Pilot's Pier, and being pierced by the well near the Church: it does not quite cross the island, the greenstone reappearing on the Back Bay side. Towards the Jamsetjee Breakwater and Cotton-screws the rock becomes amygdaloidal, and presents us with a considerable variety of minerals. At the Velard it seems much disturbed, the stratified and trappean rocks being mixed up together; but as it has not here been quarried to any considerable extent, and is much worn by the sea, no very distinct conception of its structure can be formed.

14. For a large expanse southward and westward of the Fort the lower rock is covered over by a recent marine deposit: so far as can be discovered from the numerous excavations that have been made in digging wells, foundations of houses, &c., the whole is a mass of trap up to the verge of the Native Town. During the month of May 1851 I examined the bottom of the wet ditch from end to end, and found no trace of anything but greenstone. This is visible all along the sea shore from the Apollo Pier to Nowrojee Hill—a mass of it rises to the surface at Bombay Green, and again near Fort George. A little beyond this, it has been quarried to a large extent, the quarry now forming a tank. The rock here, as also in the wells near the Church Gate, and so probably over this division of the island altogether, is dark coloured, hard, brittle,

and splintery, difficult to work, and not well adapted for building purposes. About a mile beyond the Fort Gate, the trap rises abruptly into a picturesque eminence of some 150 feet in elevation, called Nowrojee Hill. The harbour face of this has long been used as a quarry, and presents a perpendicular scarp of massy trap rising in blocks of great regularity in point of form, and of any size that may be desired: a bed of stratified rock, nearly horizontal, and about a foot thick, afterwards to be described, traverses the face of the precipice—a lower bed makes its appearance by the sea shore. For a quarter of a mile or more by the line of the railway, and on to the Wood-yards, the surface descends to within a little of the sea level, and then rises abruptly into the bold eminence called Mazagon Hill, attaining an altitude of about 180 feet: this, so far as it appears, consists wholly of greenstone. A little to the northward of this, the surface for three miles or so becomes nearly flat, and at the Powder Works consists of a mass of trap tuffa, of a pale greenish tint, curiously intermixed with veins of calcareous spar running through it in all directions. The tuffa extends into the interior of the island, assuming a vast diversity of forms, until cut across by the stratified rock in the Flats, which is succeeded, as already stated, by the basaltic ridge along the sea shore on the west.

15. At Chinchpoogly the greenstone once more rises into a fine bold ridge, which attains the altitude of 150 feet at Parell Flagstaff, and continues unbroken for the space of two miles. Betwixt this and the sea on the harbour side, the ground undulates in three successive ridges, nearly parallel to each other, one overhanging the shore, and one betwixt this and that just described, the two last being broken and irregular. Though the uniformity of the external aspect of these might lead to the supposition that the structure of the rocks was the same throughout, this is far from being the case. The bolder and more elevated portions of all the ridges consist of fine-grained compact greenstone, with very few minerals imbedded. In the portion of the hill south of the flagstaff, where the road crosses from Sewree to Parell, a curious mass of tuffa intrudes itself; externally, it is so blackened with the weather as not to strike the eye as in any way differing materially from the rocks around—when fresh broken, it is for the most part almost white. It will be found more minutely described under trap tuffa. Each of the ridges rests on a series of strata full of organic remains, and which, with the tuffas, occupy a very extensive space betwixt the beds of trap. The fort of Sewree is built upon a mass of black rock, which might at first be readily mistaken for basalt—it is, in fact, a Lydian stone, a black jasper or chert, the result, most probably, of the action of the volcanic rocks around on a stratified clay bed: the strata are still traceable in the midst of the fusion to which they have been subjected. A series

of flats, from which the sea is excluded artificially, and on which salt is extensively made, here prevail, and the surface of the island seldom at this place rises more than a few feet above high-water mark, and generally bears obvious traces of submergence. A beautiful group of little hills make their appearance opposite the old artillery grounds, Matoonga, and so continue to Sion, at the extreme end of the island. The southernmost of these consists of the jaspideous rock, or chert, of which Sewree Fort is composed, the rest in general of various descriptions of trap tuffa, with occasional exhibitions of greenstone.

The Centre of the Island.

16. Betwixt the two sets of ridges just described—the basaltic ridge from Malabar Point to Bassein, and the greenstone and tuffaceous series of eminences from the Lighthouse to Sion Fort,—the island is almost perfectly flat, about a fourth of it being in reality under the level of the sea, the waters of which are excluded by embankments, walls, and sluices. This space is covered over with various sorts of alluvium, afterwards to be described, mostly of marine, and much of it of very recent origin. Though recent railway operations, with the excavations for the supply of water during the dry season, have helped to enable me to trace formations here completely concealed by the superficial beds, a very imperfect idea is all that can be afforded of the character or position of the rocks constituting the lower parts of the island, though there is much reason to believe them mostly soft argillaceous stratified beds, such as prevail at Love Grove Sluices, and near Sewree.

17. It is quite clear that at a comparatively recent date, probably within the human period, Western India has suffered from a succession of upheavals and depressions, and that just before the latest of these, instead of a single island, Bombay consisted of a group of at least seven islands. Still more recently than this, and quite within the reach of tradition, if not of history, Colaba formed two islands, and Bombay itself either three or four, these being united at low-water, the sea at spring tides effectually dividing them from each other. Mahim is mentioned in an old MS. as forming a distinct island, and it is mentioned as still so continuing when Dr. Freyer visited Bombay in 1680. "In the middle of the island," says he, "between Parell and Mayem [Mahim], Seeam [Sion], and Bombaim, is an hollow wherein is received a branch [of the sea] running out at three several places, which drowns 40,000 acres of good land; athwart which from Parell to Mayem are the ruins of a stone causeway, made by pennances."* The three places where the sea found admission are clearly at the Worlee and the Sion Sluices,

* New Account of Persia and the East Indies, betwixt 1680 and 1688. By Dr. Freyer, F.R.S., 1 vol. fol. London, 1697.

and the openings at the Mahaluximee and Love Grove Velard, which would at once constitute Mahim town and woods, Worlee Hill, and Love Grove, into three separate islands,—their insular condition continuing till the construction of the walls now uniting them excluded the sea.

18. The neighbourhood of the Mazagon Gaol is termed *Omarkadee*, *kadee* being the word always applied to salt-water creeks dry at ebb tides: the neighbourhood of the temple of Mombadavi is called Pae Dhonee, or the place of the feet-washing, and traditions still exist to the effect that the sea flowed from the west up to the former of these, until excluded by the embankment from Mahaluximee to Love Grove, constructed above a century ago. Pae Dhonee was a ferry, where persons arriving from Salsette used to wash their feet in a salt creek in approaching Bombay; Mahaluximee was formerly only accessible from Bombay by boats.* It is singular that we should have no more direct information than this to go upon as to the physical condition of Bombay when surrendered by the Portuguese to the English little more than two centuries ago; but it is clear, from what we know, that at this period Colaba formed two islands, the lesser of these being known as Old Woman's Island, described by Dr. Freyer as " a dry sandy spot, of no further value to the Company than as affording grass to their antelopes and other beasts of pleasure." The space now occupied by the Fort, and a part of the Native Town up to Pae Dhonee, formed a second, and it is probable, from the aspect of the shore, that this was united to Malabar Hill by the sandy ridge betwixt Girgaum road and the sea,—a very slight diminution of the existing altitude would have allowed the sea to sweep clean through from Mahim to Back Bay. Though the sea must at no distant period have swept across from Love Grove to the Harbour just to the south of Chinchpoogly Hill, it is not quite apparent that it did so within the time specified; at present the Parell road is considerably under high-water mark. From this on to Sion, the land must have been continuous back to the period when the existing levels were established. The last upheaval seems to have elevated the island from eight to ten feet, and a depression to this extent would have greatly multiplied the number of islands constituting the group; the sandy flats, subsequently only covered over at high-water, being then for the most part in a state of continual submergence. The scenery must then have been still more picturesque than at present, when yet more beautiful by Nature, and undeformed by the outrages on architecture prevailing amongst us.

* Abridged from a very able paper by Mr. Murphy on the Aborigines of Bombay, in the 1st vol. of the Transactions of the Bombay Geographical Society.

19. If the reader has carefully consulted the map and sections while perusing the text, he may probably consider the general topographical account of the island just given sufficient: it includes in it some of the information about to be furnished in detail, and therefore involves me in some repetition: the apparent clumsiness arising from this will probably be more easily excused than the obscurity which might have followed the want of it. In the following detailed description, I shall take the surface formations first, and so proceed downwards.

Detailed Description.—Lagoon Formation.

20. *Alluvium.*—1, Lagoon Formation; 2, Littoral Concrete, or raised Sea Beaches; 3, Blue Clay, or submerged and reclaimed Silt; 4, Lower Alluvium, or Old Marine Clay; 5, Red Earth.

21. The uppermost and most recent is that to be met with all over the Flats in the centre, and salt-pans on the eastern side, of the island, denoted by the bright blue on the map. It is of somewhat uncertain depth—it is nothing more than the sea sludge comminuted trap, deposited before the waters of the ocean were shut out artificially from the region where it prevails, and so back to the period when the island began to emerge from its previous depression to its present level. We have thus two blue clay formations, running both in point of time and composition into each other, and betwixt which, unless where beds of different character intervene, no distinct line of demarcation can be drawn. The very appropriate name of Lagoon Formation was conferred on the uppermost of these by the late distinguished and lamented Captain Newbold. Our Flats still occasionally appear as a lagoon, when the sluices are left open at spring tides, and on these occasions, of course, a slight addition, identical with the deposit, is made. The Lagoon Formation, though in certain circumstances gliding insensibly into the old blue clay of a former age, is in general, chronologically speaking, separated from it by a very distinct and well-defined variety of rock, on which I have conferred the name of Littoral Concrete. Before things can be made intelligible, I must be permitted a few preliminary remarks in reference to the two formations just referred to.

Evidences of an Upheaval and Depression all along the Shores of India,—probably of the World.

22. The Alluvium around Bombay commonly prevails in some such state as the following :—

1st. Ten feet above the sea. 1, Sea-shells, and sea-gravel and sand, loose, or cemented into a variety of open shell limestone, 3 to 10 feet thick, called Littoral Concrete.*

* Near the fishing village of Sewree, on the Parell side close by the shore, a bed of brown earth about fifty yards in length, uncertain in extent, reposes on the Littoral Concrete, and a

2nd. Blue Clay, full of mangrove roots,—sometimes but slightly, sometimes entirely, decayed,—always in the position in which they grew, and perfectly undisturbed.

3rd. Rock. Or sometimes the following :—

1. Littoral Concrete.

2. Rock. Or,

1. Blue Clay, with mangrove roots, as before. 2. Yellowish brown clay, with concrete in the ordinary forms. I have not met with all these at one place complete, but have no doubt that they are to be found in abundance.

23. From this arrangement the following inferences are deducible: —1. At the time the mangroves grew, the blue clay must have existed at about half-tide mark, the mangrove being a salt-water littoral plant, only found some way within tide mark. 2. Before the large masses of shells and gravel could have been brought into existence, the mangrove-bearing beds must have sunk so as to suffer the sea to wash over them, and the shell deposits to accumulate, and the downward movement must have extended sufficiently far to permit the uppermost portion of these to be occasionally at least under high-water: it is regularly stratified, and contains the heaviest and largest sized shells now found on our shores disseminated equally throughout; has not the slightest appearance of sand-drift, and could in no other way, save that explained, have come into existence. 3. It could only have reached its present position by a subsequent upheaval, which brought matters into pretty nearly their present position.*

24. That these things have been brought about by movements of the land, not by advances and recessions of the sea, is obvious, from the diversity of levels at which the various beds are found, and the obliquity, and frequent incurvation and dislocation, of the strata; this last being peculiarly manifest opposite the village of Sewree, where they

second bed of similar depth, formerly cultivated as garden ground, and irrigated by finely-built conduits, appears. In the mass itself I have not been able to discover any remains strictly belonging to it. On being dug through, the concrete is always found below—it is probably an upper bed of sea silt changed by cultivation. I have been unable to determine its character, and as it is *possible* it may have been brought there artificially, I have not noticed it in the text.

* This will be found pretty fully adverted to in the Annual Report of the Society, read May 1850. I subsequently prepared a paper on the subject, which was published in the Edinburgh Philosophical Journal (Jameson's), and in the Transactions of the Bengal Asiatic Society: and, a considerable additional supply of facts having reached me, prepared another for the British Association. It was read at Ipswich in January 1851, and will, I presume, appear in their Transactions. Parallels to these phenomena will be found in the upheavals and depressions which have actually occurred at Chittagong, and along the Arracan Coast, within less than a century of the present time.

dip towards the east, in a direction the opposite of that of the fresh-water beds contained in the Trap, which come afterwards to be described. Near Sion the soil of the rice fields, obviously composed of the blue clay, altered by cultivation, is considerably higher than some of the older alluvia along the line of the Mahim road beyond Byculla, over which no recent marine deposits can be traced, though in reality they are at present several feet below spring tides. The depressing process would seem here to be still in progress ; we have no reason to suppose this to have been subject to tidal inundation 170 years ago, when Dr. Freyer wrote, though he distinctly describes the isolation of Love Grove and Mahim.

Littoral Concrete, of Shell Gravel Deposit.

25. *Its Character.*—As we have no river or recent fresh-water deposits, the upper marine beds constitute the newest of our formations, seeming to belong to the post-pliocene, or recent deposits, the materials of which they consist being identical with those now on the sea shore. The mass varies from 10 or 12 feet to a few inches in thickness : it is in general laid down in regular beds, for the most part pretty nearly horizontal, and having no appearance whatever of drift. The material is sometimes perfectly loose, and without any mineralisation whatever: most frequently it is united by a calcareous cement into a tolerably firm shelly rock. The larger shells are often filled full of spar, and on many occasions the external coating is all that remains of them, the walls of the shell itself being transformed into crystalline limestone. In this form it constitutes a valuable building stone. It is a curious fact, that it often appears in these two opposite conditions in places closely contiguous to each other. On the western half of the Esplanade, fron near the Church Gate road to the Native Town, it is in the condition of rock. Near the Native Town more especially it is highly crystalline, the material excavated from the Dhobee Tank in April and May 1851 being to the depth of twenty feet continuously* crystallised throughout. To the eastward again of the Wellesley Monument, and all along from the Cooperage to Malabar Hill, within from 100 to 200 yards of the shore, the material is perfectly loose from the surface down: it abounds in fresh water, and notwithstanding the porousness of the soil, is favourable for the purposes of cultivation.

26. In excavating two large wells near the Wellesley Monument, the shell-gravel was found to extend down 18 feet, to the Trap ; the lower beds, being of sand, were being dug through, when the water flowed so freely at the driest part of the season that it materially interrupted the work. Here large masses of coral were found, such as is now growing in Back Bay : it occupied the position in which it grew,

* See Reports of the Bombay Geographical Society for April, p. 45.

and had neither suffered from decomposition, mineralisation, or abrasion. This variety of coral never appears on our shores as a rock, for, having attained the thickness of 6 or 8 inches, and an area of a square foot or two at the outside, the zoophyte seems to die, and the stony covering to become detached. On this the coral almost immediately becomes abraded and worn, and is found in rolled masses on the beach. The inference from the condition of the coral found under the shell gravel on the Esplanade is that it was suddenly submerged, and at once buried so deep in sand and gravel that it was beyond the reach of further injury: how the water which pervades the whole shelly and arenaceous beds in Bombay should within such narrow limits be possessed of such different properties—crystallising the shells at one place, and filling up their cavities into a solid crystalline mass, and leaving the whole gravelly mass unaffected in others close by—is not easily explained.

27. Where the shells are generally cemented and mixed with argillaceous matter, as, for example, where the railway cuts through the road opposite Mahim Wood, and again near Sewree Fort, the formation becomes exceedingly hard and compact, with an earthy in place of a crystalline appearance.

28. *Where found.*—The formation, the peculiarities of which have thus minutely been described, first makes its appearance on the sea shore south of the Lighthouse, and forms the graveyard at the root of the Prongs. On the Harbour side of the island it reaches along the shore as far as the Pilot's Pier, constituting a considerable portion of the Observatory compound up to the level of about ten feet above the sea. It forms the grounds of the Lunatic Asylum, and the drill-ground betwixt the Catholic Chapel and Cabool Church, and so extends wherever the level of the ground does not exceed 12 feet, to the end of Colaba, near Bombay. A large portion of the lower part of the Fort is built on it: it forms the whole of the Esplanade, extending from the Apollo Pier to Malabar Hill, and so under the lower portions of the Native Town. It appears a hard compact rock a little to the eastward of the Gowalla Tank; near the Garden House of Juggonath Sunkersett it exists as loose shell gravel; a little beyond this it vanishes. Around the base of the hills, near Mahaluximee, and close up to the end of the Love Grove Velard, it narrows out into a thin border of gravel, and so continues by the shores of Love Grove and Worlee Hill. The whole of the level cocoanut grounds which constitute Mahim Wood are formed of it, and it forms the little neck on which the fishing village stands connecting the castle rock of Sewree with the hill. It is found all along the low shores of Salsette, Versova, and the islands to the north, and the whole of the low grounds by the shore to the southward. A

large isolated mass of it presents itself on the line of the railway, most opportunely for the ballasting of the work, near the haystacks, half way betwixt Byculla and the road to Parell. The material here is loose and incoherent, and it abounds with the fragments of kunkur from the blue clay, and the calcareous tubes from the mangrove roots about to be described. From this circumstance it seems likely to be still more recent in its formation than the substances referred to, which do not appear to have come into existence till after the emergence of the blue clay with the concrete over it from the sea. This mass of gravel, which is altogether imbedded, is at present below the level of high-water mark.

Blue Clay, with Kunkur, and Mangrove Roots.

29. *Character.*—Immediately beneath the formation just described, unless where this rests directly on the rock, is a bed of bright blue clay, highly calcareous and charged with salt, nearly identical in appearance with the sludge in our estuaries and along the shore. It varies from a few inches to several feet in thickness; its upper margin is at present about a foot or so below high-water mark. It generally abounds with the roots of the mangrove, obviously still remaining in the position where they grew; the fragments of the stem stand some inches above the clay. I have never been able to find any remains of them in the concrete above. The hue and substance of the wood is in some cases but little changed; the fibres are still tough, their colour red, and somewhat more dark than that of mahogany. For the most part, however, the roots are cemented into a black, softish, peaty matter, which crumbles in the hand: it cracks in drying, and when dry is brittle and lustrous, like coal. It burns without either flame or smoke: long exposed in the damp, it first becomes coated with a thin film of sulphur, its cracks being occasionally filled with pyriteous matter. Occasionally it becomes covered over with beautiful greenish white spiculæ of sulphate of iron. This salt is so abundant in the lignite beds near Quilon as to be collected and made use of for the purposes of the dyer. The clay is full of nodular masses of greyish coloured limestone, from the size of a pellet of small shot to that of the hand,—a variety of the substance called Kunkur, which prevails all over India, and furnishes the bulk of the mortar used in building.* The Kunkur of the Blue Clay Formation is remarkable for the extraordinary resemblance its nodules bear in point of form to common chalk flints; a resemblance so striking that, but for a slight difference in point of tint, the most practised eye could not discriminate betwixt them.

30. The mangrove roots are full of perforations, obviously made by

* For a description of Kunkur, see Note C, Trans. Bombay Geograph. Soc. vol. x. p. 220.

some marine worm; they vary from the thickness of a goose-quill to that of the thumb.

These borings often extend for several feet in a line continuously : they are invariably coated with a lining of pinkish white carbonate of lime, varying from a few lines to a sixteenth of an inch in thickness. Its tint and texture is not unlike that of some varieties of satin spar; it is crystalline throughout, but has evidently been deposited in successive layers, of which fifteen or twenty may occasionally be counted. It seems probable that the outermost of these coatings may have been deposited by the worm which bored the hole—similar borings, but of very much smaller dimensions, are still found in the decayed specimens of the root of the mangrove growing on our shores, the calcareous coating being in this case, however, as thin as paper, and equally polished on both sides; and that this was thickened afterwards by deposits of pure carbonate of lime from the rain water of the monsoon,* this at times going on till two-thirds of the boring are filled up by the spar. The walls of these tubes are always thickest on the lower side, especially when the deposit has been considerable, and they are generally uneven inside: outside they are smooth and polished, conforming entirely with the shape of the boring which forms the mould. When found *in situ*, these tubes are generally filled with portions of the blue clay from the surrounding beds. This in many cases is hardened into kunkur of the form of the interior of the tube, of the texture and substance of the nodules around : in many cases, the fine sparry coating has been partially or wholly eaten away or redissolved by the water, so that nothing but the kunkur core remains. The perforations and fangs of the roots have frequently been filled up from the outset with clay, which has become kunkurised, so to speak, furnishing a cast. It is very seldom that they have any internal organic structure, though I have met with a few cases of the opposite, so that they are merely casts and organic in external aspect, and partake in no way beyond this in the character of petrifactions. The best open section of the relation betwixt the concrete and blue clay is that on Sewree beach, where all the characteristics of both formations are fully manifested, and it will be seen from the lithographs that the appearance presented by it is not unlike that of the dirt bed of Portland.

31. The blue clay, with the mangrove roots, and all the other characteristics already referred to, is found in all the wells I have met with in Mahim Wood, and in most of those under the western portion of the Esplanade, the same as at Sewree; as also along the line of the Grant Road, and so to Juggonath Sunkersett's house ; it crops out under the sands betwixt the rocks in the upper part of Back Bay and the Sanita-

* This explanation is suggested by Mr. Carter, to whom I have submitted specimens of all the varieties of encrusted borings ; it seems to meet the circumstances of the case.

rium; it is found forming the rice fields betwixt Matoonga graveyard and Sion, transformed into the ordinary brown earth of our higher grounds, and recognisable chiefly from the tubes which indicate the former existence of mangrove roots.

32. Whenever the excavations in the places enumerated are first made, a very powerful effusion of sulphuretted hydrogen gas is emitted,—so much so at times as to give a taste to the water and taint the air around. I have met with no good section near Sion or in the higher portion of the Flats betwixt the Club and Love Grove, but the Kunkur and the tubes abound on the surface in both of these localities: I have no doubt the arrangements are the same. When tolerably free of salt, the Blue Clay, as in the case of that under the Esplanade, answers for pottery purposes, but it shrinks greatly, and is apt to warp in drying; it burns into a dirty yellowish red. When much contaminated with salt, as is the case of that in the Flats, it is most difficult to sweeten it: I have washed specimens of it in a tub for the whole course of a monsoon, and to the last, found the water with which it was washed slightly salt to the taste. When thrown or moulded in this state it promises admirably, and turns when green like fine horn; the moment it is further dried it crumbles to pieces.

33. Along the line of the railway, betwixt Mahim Road and Sion, the concrete is awanting—the blue clay extends from the surface down to the rock. The Lagoon Formation, or newer clay, covers the fractured portion of the mangroves, here penetrating to the depth of from one to two feet, the railway cuttings furnishing excellent exhibitions of both. Here selenite is found in abundance, filling up in plates the cracks of the clay. The plates are generally oval, thinning out at the edges all round; sometimes they are lenticular: they vary in size from an inch to four inches in their larger, and about half as much in their smaller diameter, and from one-sixteenth to half an inch thick. Externally they are rough and earthy, of a greenish or yellowish brown tint: when held up betwixt the eye and the light, a beautiful feather-like object makes its appearance along the axis of crystallisation—it can be rendered beautifully distinct by grinding the specimens on their thinnest side, then polishing them. The selenite plates are always found on edge, and they split with much ease with a perfectly smooth and brilliant surface and even texture, in the direction of their larger axis, and at right angles to their plane: this, so far as I have observed, holds uniformly, and forms a striking contrast to the more extensive deposits of the same mineral in the deserts of Egypt and of Sind, where in the great majority of cases the plates do not break across, but split in the plane of the plate, or parallel to the plane of the walls of the vein. I have not met with any fibrous or compact specimens of the mineral in Bombay; they are

plentiful in Sind and Egypt. The formation of the selenite, like that of the kunkur, is now in progress, and is very easily explained. The sulphates of soda and magnesia of the sea salt decompose the carbonate of lime, and afford carbonate of soda and magnesia, which at Bombay is washed away by the rains, and sulphate of lime or selenite remains.*

34. In cutting the town drain vast masses of oyster shells were excavated from the blue clay about 5 feet under the surface, to the southward of the Grant Road, and nearly opposite the Grant Medical College; and again in the railway cuttings opposite Parell, and near the village of Matoonga: they seem identical with those now abounding on our shores. They are of very large dimensions, and a single mass of them adhering firmly together was sometimes detached nearly half a ton in weight. The surface of the ground here is set down by Mr. Conybeare as about two feet under high-water spring tides, so that the surface of this portion of the island must a century since have been liable to occasional submergence.

Lower Alluvium.—Yellow Earth.

35. The cuttings through the Flats along the line of the railway afford an excellent exhibition of a third alluvial formation, obviously of much older date than the blue clay: it is of a chesnut-brown, or yellowish brown colour, the tint becoming lighter as we recede from the surface. It is less liable to crack during the hot weather than the blue clay, especially where regularly cultivated: in moist, or seldom tilled spots, such as those around the Byculla Schools, it cracks and splits in all directions, the fissures often extending several feet into the ground, —the earth where freshly excavated presenting in many cases a glossy striated appearance in the walls of the fissures. I have never met in these beds with any fragments of wood or other vegetable matter truly belonging to them, and they are nearly devoid of all organic remains. I felt at a loss whether to assume it to be of marine or lacustrine origin, when the excavation of a large tank near the railway, betwixt the Bishop's house and the Byculla Schools, solved the difficulty. The surface here, as estimated by the line of the railway, is 20 feet above the level of the sea—at least 8 feet higher than the most elevated of the newer marine formation. Six feet under this the yellow earth was found to abound with nodules of kunkur, of a hard arenaceous semi-crystalline texture: a piece of the shell of the thin paper or pearl oyster formed the nucleus of each nodule; the shells where not protected by an encrustation of kunkur had all apparently been dissolved out. This solved the question: the lower alluvium had originally been a marine deposit,—blue clay, or silt most probably,—which, on being

* See Note D, Trans. Bombay Geograph. Soc. vol. x. p. 225.

elevated and long exposed to the air and rain, had had the marine remains, and probably the original flint-like nodules of kunkur, dissolved out of it. Common oyster and other shells were afterwards found in fragments, but not in such numbers as to enable the age of the formation to be determined. The kunkur with which the lower alluvium abounds is of a somewhat paler tint than the soil itself: it is the same in point of external appearance as that generally prevalent in the interior, and bears no resemblance whatever to the smooth and fantastically shaped nodules found in the blue clay. It is rough and amorphous, often runs out into long branches like coral, and has always a fibre of grass, or some other vegetable, shell, or mineral substance, in the centre—the primary nucleus, around which the lime had originally deposited itself. In the absence of woody matter the peculiar form of the kunkur and aspect of the soil itself makes this readily distinguishable from the formations just over it; though, if it was, as I have assumed, originally a marine formation, the cause of these differences is not easily explained. It is probable, at the same time, that the nodular kunkur found in the salt clay may, by long exposure to the action of fresh water, have been redissolved, and the lime contained in it a second time thrown down in the form in which it is now found. The lower alluvium forms the soil of nearly all the higher portions of the island, with the exception of those where the substance about to be described—the Red Earth—takes its place. Betwixt the railway and Byculla it is about 20 feet above the level of the sea: it is found to the depth of 15 feet from the surface, and is nearly uniform in its appearance throughout. At Mr. Dickenson's house, again, as already stated, and so along the Mahim Road, and across towards Chinchpoogly, it is several feet under the level of the sea: yet no *recent* marine deposit is discernible over it, furnishing a presumption that a considerable amount of subsidence has occurred since the tide was excluded by the works betwixt Mahaluximee and Love Grove about a century ago, at which time it must, it would seem, have been higher than at present.

Red Earth; Decomposed Trap.

36. *Lall Muttee* of the Natives. I am not aware that the two preceding formations have any particular name or designation amongst the natives. That about to be described is called *Lall Muttee*, or red earth, in contradistinction, apparently, to the ordinary soil on the one hand, and the moorum on the other; the term moorum being indiscriminately applied to decomposing trap, soft sedimentary rock, or anything which is too hard for agricultural and too soft for building purposes. It seems unfortunate that a term of such vague significance and general application should not, when used by men of science, have the precise

meaning to be in each particular case attached to it explained. The red earth, so far as I know,* is always found lying immediately over greenstone, or some similar variety of friable trap: I have never, unless in Salsette (see para. 38), met with tuffa, much less with sedimentary rocks under it. It is of a brightish or brownish red colour, nearly that of brick dust. About two-thirds of the whole consists of stony pieces, about the size and form of horse beans. These are for the most part glazed and shining externally—internally they are black and earthy, like softish trap. The matter in which they are imbedded, when washed out and by itself, forms a fine plastic red clay, which suits well for the purpose of the potter, being easily moulded or thrown, and standing a very high degree of heat without softening or warping: all our other clays fuze at a red heat, and are most intractable as material for pottery. It requires some forethought and preparation to procure it in sufficient quantity for the potter; and, wretched as is our other material, it seems never to have been thought of for pottery purposes, till a large bed of the finer portions washed free of stones was deposited by the monsoon of 1851 close by our School of Industry brick-field, and its qualities thus became immediately known to us. On first being exposed to the air, or subjected to cultivation, it refuses to sustain vegetable life; no plant whatever will grow upon it, and it remains without vegetation during the wettest season, when the rocks themselves are almost green. With moderate manuring its character in a few months' time becomes completely altered,—the stony pieces disappear from it, it changes its colour from red to brown, and becomes a fine uniform unctuous soil, remarkable for its fertility: the alteration may be effected in a few weeks' time during the rains, and then it becomes fertile in the extreme, each successive crop improving its qualities and texture. It is greatly sought after by gardeners for mixing up with the other more promising-looking, but in reality less productive soils. In the Red Earth large concretionary masses, from the size of the fist to that of the head, or upwards, are frequently found, to all appearance aggregations of the earth itself. Externally they are glazed and of an even texture; internally they are compact, corroded, and vesicular,—so perfectly like the more ordinary varieties of laterite that it is difficult to distinguish the one from the other,—the only difference betwixt the two being that the one is a shade more rusty in its tint than the other. These concretions are often seen to all appearance in the act of forming—they are much heavier and more compact than a similar volume of red earth, and yield with consi-

* The reader must be cautioned as to the weight to be attached to my authority on this matter. Tied down by professional avocations to Bombay, my observation has been in a great measure limited to the island, and though it is impossible wholly to avoid generalisation, it must be remarked that I have generalised on very limited data.

derable difficulty to the hammer. Crystals of siliceous spar, and a curious variety of laminated quartz, are found imbedded in the red earth : I have not met with any other trappean minerals in it, but then I have not happened to fall in with specimens of the earth near any of the rocks in which minerals abound.

37. *Situation.*—The red earth is always found on the surface of trap, often in immediate contact with it, and enveloping it on all sides, though there generally is a mass of rusty-coloured or yellowish earthy matter, obviously the rock in a state of decomposition, between them. For five or six feet occasionally it is entirely free of rock, and is throughout of perfectly uniform hue and texture. In general, however, numberless masses of boulder trap, from a few inches to several feet in diameter, are found thickly imbedded in it : it fills up the intervals betwixt the masses of trap, to the depth of 15 or 20 feet, and is occasionally found beneath them ; I have never met with it lower down, and the lowest loose matter amongst our traps is soft yellow ochry earth, obviously the result of decomposition, and which is found in all stages of decay. I have not met with it, at the surface, in point of level anywhere so low down as our recent marine formations, so as to be able to observe the effect on it of having been submerged. The boundaries of the red earth are abrupt, and it seldom shades or merges into any other rock ; the trap in contact with it seldom manifests signs of decay ; the earth is never stratified, and exhibits no appearance of watery deposition ; and amidst the difficulties of explaining its appearance, I have come to the conclusion that the probabilities on the whole are in favour of its being of trappean origin, or rather of its being trap in a state of decomposition, hard as it is to reconcile this assumption with many of the most notable circumstances attending it.

38. Red Earth abounds at the southern extremity of Colaba, over the Greenstone around the Observatory ; it forms an integument over the Basalt of Malabar Hill ; it prevails in large masses along the ridge betwixt Chinchpoogly Hill and the sea, near the School of Industry. The railway passes through a deep cutting beyond Sion, just as it enters the island of Salsette ; the rock here is a purplish tuffa, which will by and bye be described (see extract from Mr. Carter's paper, para. 42). The Red Earth is of a brownish tint, much less red than it generally is, more friable and fertile looking, and free of the small stony particles which characterise it. I have not met with any ferruginous concretions in this variety of rock. The peculiarities under agricultural treatment are given from my own observation as a cultivator. The red earth presents us with a striking contrast in this matter with the regur or cotton soil, which is distinguished for its fertility from the outset, without requiring any aid whatever from manure for centuries of

constant cultivation : the Red Earth is fertile only when fed with organic matter. If both be, as has very often been supposed, the *débris* of the Trap on which they rest, no two substances ever owned a common origin in all their characteristic features so perfectly dissimilar.

Erratic Masses.

39. *Laterite.*—This closes the list of our true alluvia ; and before proceeding to describe the older rocks, a short notice of the erratics, few in number as they are, may here be given. Though granites of all descriptions, five or six varieties of limestone, quartz, hornstone, &c. &c., are occasionally to be found on our shores, Laterite* is the only one deserving the name of erratic, the other rocks and specimens, with the exception of the hornstone, appearing all to arrive in the form of ship's ballast.

The nearest point at which this singular rock occurs *in situ* is thirty miles off: though great abundance of it in all its varieties is to be met with all around our shores, I have not fallen in with any specimens of it in the interior of the island. It is found on the little island of Kenery, separated by seven miles of deep channel from the mainland ; along the shores of Versova and Salsette, and so on to Gogo, on the further side of the Gulf of Cambay, by which it is cut off from all the laterite formations ; —it is not found in Kattiawar ; how much further north I know not, this being the limit of my experience. Great blocks of it are seen built into the fort and walls of Surat, brought, I presume, from the sea shore to the northward along with the other building material, there being no stone of any sort in the neighbourhood. In absence of all idea of glacial action, the only explanation that can be given of the appearance in such abundance of a rock so heavy, so loose in its texture, so friable and apt to suffer from disintegration, at such distances from its proper habitat, is that at no great distance of time it prevailed over a larger area than that which it now occupies, and that the fragments now found are the scanty remains of the masses removed by denudation before the emergence from the sea of the lands over which they prevail. I admit that this seems a strained and is a very ill-supported hypothesis, yet I know not what other there is that will so well explain either appearance. The abundance in which the Laterite is found prevents the idea of artificial transportation. I have *thought* I could sometimes detect it imbedded in the blue clay formation, but do not feel sufficiently assured to pronounce on the point. It is mentioned by Mr. Prinsep as amongst the materials brought up by the boring tools from the Delta of the Ganges in seeking for water at Calcutta, and is probably the fer-

* I have seen reason to change my views on the subject of Laterite since 1852, and now feel convinced of its being decomposed Trap, assuming an infinitude of different forms.

ruginous clay found in the borings at Madras: in both these cases it might have been brought by streams from the mountains under the present state of the earth's surfaee.

Fresh-Water Beds alternating with Trap.*

40. The outerop of the fresh-water beds is almost invariably under high-water mark, both on the shores and in the interior of the island, and in the latter ease it is covered over with a thick mass of alluvium, whieh, being mostly salt, has seldom been dug through in search of fresh water. There are no streams or river ehannels, and no euts or exeavations of any considerable magnitude aeross the strike of the rocks, and, with the uncertainty ereated by the sudden deseents and upheavals, disloeations and disturbanees, whieh oeeur in trap, it is not easy to pronounce with eertainty as to whether there may not be some faults, slips, or inversions, amongst the strata which have not yet been observed; there is no evidence that there are. My eonvietion is that there are not any of these things to be met with from side to side of the island; and under this hypothesis, there are at least six separate deposits of sedimentary matter eropping out betwixt Love Grove and Sewree, a distanee of five miles across the surface, or of probably less than half a mile, say two thousand feet, in a line at right angles to the plane of the strata. It is very probable that it is to the alternation of beds of trap and sedimentary strata, arranged horizontally or nearly so, that the remarkable stratified appearance, which renders the mural preeipiees of the Western Ghàts so pieturesque, is due. The uneertainty as to the number of separate beds is inereased by finding one of these at Sewree divided into two by the intrusion of a mass of trap in the middle of the bed, and similar things may probably be found to have oecurred more than onee.

41. I have assumed the beds whieh protrude from under Malabar Hill to be an extension of those seen at Mahaluximee, at Love Grove, and again at Worlee: from the Wood-staeks to the base of Tardeo Hill, and again from Mahaluximee to elose by the Sluices, and in a straight line from this to the extreme end of Worlee Hill, the rock is hid under alluvium, and there are various similar beds elose at hand. So far as the outcrop is visible along the sea shore, the beds under Malabar Hill are of a pale oehry yellow; they dip at an angle of about 15° W. and

* "The island of Bombay is eomposed of five or six bands of trap roek, ehiefly greenstone and amygdaloid, eonformable, dipping west, at about 10° or 15°, and separated by beds that have the appearanee of being of sedimentary origin, though there is no aetual proof of the faet."—Clarke on the Geology of the Neighbourhood of Bombay. Trans. London Geol. Society, vol. iii. 1847, p. 221. "There is now, as will be seen, great abundanee of proof, not only of the sedimentary, but of the fresh-water origin of all the beds."—Faleoner's Aecount of Perim.—Geol. Journal. Dr. Lush eonsidered the sedimentary rocks of Bombay above the trap—they, in faet, alternate with it.

by S., and seem about 40 feet in thickness, conjoining the perpendicular scarp in the cliff with that showing itself horizontally under the tide. The upper beds, as exposed, are much less friable than the under ones. Some feet below the trap large compact masses, containing small scales of mica, have been met with : some of these are perfectly black, charged with carbon ; when freshly broken they smell strongly of naphtha, and might readily be mistaken for strata of the coal formation. Some of them abound in small crystals of sulphuret of iron, supposed by the natives, when first found, to contain gold. Impressions of reeds and grasses are found in abundance both on the black and yellow shales ; I have not met with any other remains, but have no doubt that they exist in abundance. The beds first show themselves about half a mile inland from Malabar Point, where they emerge somewhat suddenly from under the basalt ; they are not traceable on the other side of the hill. They continue along the line of the public road and sea shore for about two miles, when they are buried by the marine deposits from the Wood-stacks up to near the Gowalla Tank. Here I have met with them in the bottom of several wells near the country residence of Juggonath Sunkersett. They are once more lost sight of till seen again in an excavation at the edge of the Flats opposite the Bee Hive, near Mahaluximee, and near the Velard ; and just on the seaward side of this, on the beach opposite the residence of Sir Jamsetjee Jejeebhoy, the strata are seen set on edge striking out betwixt two beds of trap till they thin away into a point. The bed reappears, in the same line as that in which it is last seen, betwixt the sea and shingle beach below the low precipitous cliff under the temple of Ram Hill, which forms the southern part of the Love Grove group of eminences. Here the strata are nearly horizontal, the colour of the rock a somewhat brownish yellow ; the mass visible is about three feet in thickness. Both towards the land and round by the sea shore, it disappears under the basalt, and continues for half a mile invisible. it reappears for about thirty yards on the sea shore, about half way betwixt Mr. Smith's house and the Sluices. Here, where the covering of basalt is awanting, it has been pierced by a well, and water found in abundance.

42. 2. *Love Grove Beds.*—The extensive cutting for the debouchure of the town drain, at the Sluices near Worlee Hill, affords a beautiful section of the trap and stratified rocks. The general level of the island is so close on that of high-water that a canal two miles in length required to be cut before a proper point of discharge could be found for it, and here a cut 30 feet across, 1,000 in length (the continuation of the canal to seaward), and 16 in depth, required to be made, to enable it to secure sufficient scour from the sea. The cut traverses a little

natural valley, betwixt a hillock of basalt, part of the Love Grove ridge, and the southern end of Worlee Hill. The stratified rock along the valley appears at the surface, and is seen to descend at both sides under the trap, dipping to the W. and by S. at an angle of about 12°, in a tolerably even plain. The upper beds are of a dirty yellowish colour for about from one to two feet down: to this a mass of perfectly black strata, highly bituminous, succeeds. It smells strongly of coal tar when fresh broken, and smokes, loses weight, and changes colour, in the fire. It abounds in impressions of reeds and grasses, and here also skeletons of frogs and tortoises are to be found.* Just at the Sluices the regularity of the beds has been disturbed, and they dip for a little in all directions. Here they are surmounted by a large mass of basalt, rising into a little hill: more towards the sea they crop out again, the basalt disappearing; and from high-water mark out to sea they are covered over with a mantle of basalt broken into fragments, and from two to four feet in thickness: and this state of matters continues till the rock disappears under the ocean. The lower beds of these strata are full of nodules and septaria, and seem to have been much disturbed in comparison with the upper or rather the middle strata, which look as if laid down in a state of great repose; and the cause speedily becomes apparent. Just to the northward of the great cut, the stratified rock has for a short distance been peeled off by the sea, and the trap under it exposed to view. Its surface is corrugated and furred in all directions, consisting mostly of globular or highly vesicular masses, with every here and there pieces of semifused strata, showing clearly that the sediment had assumed its position when the melted matter impinged on it from beneath, the trap itself becoming greatly affected in its external character by the cold material with which it came in contact, while the sedimentary deposit was partially fused or chertified by the fiery mass. The stratified rock reappears again all around the end of Worlee Hill, facing the Sluices, and presents itself for a few scores of yards both along the high road and sea shore, to the northward, where it is once more lost under the basalt. Here, however, the stratified cliff is about six feet in height; the rock has been melted both above and below, showing that the trap from beneath, and that above, were both hot when they impinged on it. It has at one point been much disturbed

* "The Batrachian beds are a mass of blue rock [those under consideration] weathering into shale not unlike ordinary coal strata, containing what I have no doubt will turn out to be vegetable impressions. The upper beds are interstratified with thin seams of sandstone and argillaceous rock, and over the whole is a mantle of basalt, which cannot be less than seventy feet thick. This basalt has in parts caused imperfect fusion of the fossil beds, obliterating their stratification, and superimposing something of its own columnar or at least prismatic character."—Mr. Clarke. Proceedings of the Lond. Geol. Society, 6th Jan. 1847. All this is in perfect accordance with my own observations.

by some agency coming into operation after the fused beds had become rigid, and which thus forced the zigzag fragments of chertified rock into the middle of the mass. The fossils in this bed were first discovered by Dr. Leith in 1846, when the engineering operations were in progress, as referred to by Mr. Clarke. Just as I had nearly completed the preparation of this paper, an essay on the Geology of Bombay was read before the Bombay Branch of the Royal Asiatic Society (December 11, 1851), by Mr. H. J. Carter, of which the following is an abstract:—

"The Author stated that the island of Bombay, though unpromising in aspect geologically, was nevertheless of extreme interest in this respect; that although at first sight it might appear to be nothing more than a mass of black trap, yet that nevertheless it presented in its composition the three classes of rocks, viz. Igneous, Lacustrine, and Marine.

"That there was distinct evidence of successive effusions of the igneous rocks, and that they had been thrown up through the lacustrine strata, which were of ancient date, and had thus again been brought to the earth's surface and exposed to view.

"That the latter were deposits of fresh water there could hardly be any doubt left, since to the author's knowledge no marine fossil had been found in them, while they abounded in lacustrine ones. Dr. Leith had discovered in them species of reptiles belonging to the Chelonian and Batrachian orders; the former consisting of fresh-water tortoises, of which he had found specimens of nine or ten individuals bearing the distinguishing marks of the Pleuroderal Elodians or Marsh Tortoises, and the latter of Frogs, of which he had found numbers in two separate places widely apart: the Frogs had been called by Professor Owen, *Rana pusilla*. Entomostraceous Crustacea of the family Cypridæ prevailed throughout these lacustrine deposits, and in some parts strata were wholly composed of the shells of these little animals: there were the remains of several species of them,—one ovoid and granulated on the surface, another cylindrical, and a third discovered by Dr. Leith which had a striated rim round the large end. The author had also found several small seeds, and Dr. Leith, again, had discovered leguminous pods, like those of the tamarind tree, with roots and stems of aquatic plants, which, with pieces of various kinds of wood, abound in the lower part of these strata in a bituminised or anthracitic or coaly state, giving the whole a black carboniferous character. No positive evidence of shells had yet been met with, but the author had found, in a black chertified portion of the upper part of these strata, the section of a fossil which could hardly be taken for anything else but the remains of a shell resembling Paludina. All this proved that these strata were purely lacustrine, and hence it followed that in the position now occupied by

the island of Bombay, that is, so far as latitude and longitude are concerned, there was once a river or fresh-water lake; but it by no means followed that this lake should have been on a level with the sea, since the author had shown, in his Memoir on the Geology of the South-east Coast of Arabia, that that shore at least of the Arabian Sea had undergone an elevation and depression of more than 4,000 feet.

"Next to the Lacustrine strata in interest, perhaps, was a rock which had been called 'conglomerate,' 'trap-tuffa,' &c. This appeared to be an igneous one, which had been altered by its passage through aqueous strata and formations containing much iron. The presence of large angular portions of aqueous strata proved this, and the heterogeneous admixture of igneous and aqueous rocks in the greater part of it made it closely resemble in composition the *Rothliegendes* of the New Red Sandstone Series, also called 'Exeter Conglomerate'; while its argillaceous nature in some parts, mottled red and white and always highly ferruginous, allied it with the foregoing characters so strongly to the Laterite, that the author conceived them to be one and the same formation. There had been two or more effusions of it, because dikes of it were seen passing through masses of the same material; the hills at the northern extremity of the island were composed of it; it might be seen following the course of the lacustrine strata imbedded in the Trappite, and bursting through the latter in several places."

43. The yellow sedimentary beds continue traceable all along the landward base of Worlee Hill by the public road, occasionally manifesting themselves on the sea shore. A bold promontory of hard compact basalt runs out to seaward from the fishing village of Worlee: just behind the fort, close by the beach, there are six or seven wells, nearly adjoining to each other, all cut through the stratified rock; they are all old and moss-grown, and all I could determine of the strata was that they dipped at an angle of from 10° to 12° nearly due south. From this onward to the estuary at Mahim, the rock sinks beneath the level of the sea, and is covered over by littoral concrete. The basalt, as already stated, reappears at Bandora, and forms the promontory and ridge of Nossa Senora de Monte. The rock to the eastward of this seems mostly tuffaceous, and is, very probably, the wreck of the alluvium mingled with and altered by the intrusion of volcanic matter. It is difficult to guess the breadth of the outcrop or actual depth of this group of beds; they seem to extend fifty or sixty yards into the Flats, when they are lost beneath the alluvium, in which no wells or excavations have been made.

44. 2. *Second Set, or Byculla Club, Beds.*—In the bottom of the town drain, from the Grant Road Theatre northward to opposite the Byculla

Club, trap is uniformly found,* and on in the same general direction various quarries, now used as wells, have been opened, all in trap. It is found further on in the bottom of the cuttings on each side of the railway, till it crosses the Mahim road, reappearing afterwards in a newly opened quarry close by the railway, opposite the village of Matoonga.

45. In absence of evidence of the contrary, and with this much in favour of the hypothesis, I assume the volcanic mass to be continuous: it is probably about 100 yards across the surface. Trap is found in all the wells and other cuttings to the south-east in the same general line through the Native Town, and so probably extends right on to the sea at Back Bay. In the bottom of the town drain, again, about 100 yards to the south-east of the Grant Road, the stratified rock is met with in nearly the same form as that presented by the yellow beds at Love Grove and Malabar Hill. It seems to make a sudden turn towards the east, and was met with in the foundation of the Obstetric Institution, dipping south-easterly, very compact blue trap prevailing to the depth of thirty feet in the wells and tanks immediately adjoining. It is probably the same bed which is seen about 300 yards further on at the surface on the western margin of the Baboola Tank, or not improbably the same that presents itself in the reservoir at Paedhonee; it is either met by a second bed, or split in two by the trap. At Baboola Tank, where it dips SW. 8°, it is hardened by the volcanic mass from below upwards, and at the line of junction contains the same minerals as are found in the trap itself; the upper portions contain impressions of reeds and grasses. It is probably this bed through which the wells near the residence of Mr. Dickenson, and the former dwelling of his father, near which the Sewree and Parell roads separate are pierced, which again appears around the house of Mr. Wells, horse-dealer, and by the side of the railway opposite Government House, extending towards Matoonga. This *I assume*, on very imperfect grounds, as will be seen, to be the second fresh-water bed in the descending series: the presumptions are in favour of the hypothesis, and there seems nothing to oppose to it in the present state of our knowledge. These remarks have been made general to avoid repetition: if the reader will turn forward to where the Baboola Tank is described, he will find a minute account of the appearance of these beds.

46. 3, 4, and 5. *Lower Baboola Tank and Jail-Well, Beds.*—The 3rd, 4th, and 5th beds in the descending series are so thin, so imperfectly marked, and have been observed at so very small a number of points, that the reader is referred to the paragraphs further on, where descriptions of them appear.

* Here I have found agates, jaspers, and bloodstone in considerable quantity, such as those prevalent in the Deccan Traps. They are mostly decayed and worthless for any economical use.

47. 6. *Chinchpoogly and Parell-Hill, Beds.*—Following the line of road from the Grant College through Mazagon to the sea shore, that from Mr. and Colonel Dickenson's houses to Chinchpoogly, and that from Mahim Wood to Parell Hill, we have very tolerable means of examining the rocks in three parallel lines at right angles to their outcrop. The beds 3, 4, and 5 ought to cross this line if conformable with the others, but they are so very thin, and so easily lost sight of, that it is impossible to say whether they are non-existent, or are merely out of sight; they at all events scarcely affect the general character of the large mass of trap which now intervenes; it is nearly a mile across, and is much the most massy I have met with, its eastern edge resting on the ridges of Parell, Chinchpoogly, Mazagon, and Nowrojee Hills (Dungaree), where it is much broken up, and disturbed, and Fort George. The sedimentary rock manifests itself in masses at Chinchpoogly, where it extends about 30 feet vertically up the hill, and about 100 horizontally, and is probably in actual measure 40 feet thick: it dips nearly due west, at an angle of from 8° to 15°. It is of a light yellow ochry colour, hardened over the *upper* surface by the contact of the trap, which is much decomposed and bouldery at the point of contact. The crops of this bed are conspicuous all along, stretching away nearly due north, forming the upper formation of Chinchpoogly Hill; along the line of the Gardens of Luximon Hurrichunder, and of Parell Hill; along that of the Agricultural Society, and thence along the upper slope of the valley towards the old artillery grounds at Matoonga, being discernible in the tanks and wells as we proceed, to where it is hid under alluvium. The lower portions of this beyond the Society's Gardens are of a bluish colour, and seem to have suffered much from crushing and lateral pressure.

48. Under the Chinchpoogly Hill is a large mass of fine even-grained compact trap, which forms the ridges just to the eastward, one to the south of the Society's Gardens, on the highest point of which my house is built, 70 feet above the sea.

7. *Sewree or lowest Sedimentary Rocks.*—The *three* sedimentary beds at Sewree are so closely contiguous to each other that I have treated them as one, two of them being very obviously a single bed split into two by the intrusion of trap.

On cutting down the cliff betwixt my house and the sea with the view of obtaining material to fill up the reclaimed ground for a site for the works of the School of Industry, and a position for a brick-field, the following section was disclosed: a fragment only is here given to illustrate the text, it will be found represented in full amongst the lithographs at the end:—

49. The face of the rock here represented is about 30 feet from

c to *g*; from *a* to *g* gives a cross section of this as seen in a well partly re-opened, partly sunk 6 feet under the level of *c*.

50. The burst of the trap through the whole three beds of stratified rock I had unfortunately no means of tracing lower down or further out than is here represented. The stratified beds were examined a little out to sea, and found unbroken, so that it did not extend as a vein further in this direction. The melted matter has here split one large mass of strata into three, pressing them down, and distorting them, as above exhibited—the proof of the intrusion rests on this, that the upper surface of *c* and lower one of *e* are completely melted, the stratified portions being in general from two to four inches in thickness, sometimes as much as eight or ten at the sharp salient angles : the same seems the case with the upper and lower beds of stratified matter, but there it is not so obvious, the beds being much less perfectly exposed. The stratified rock abounds in marks of reeds and grasses. I have not met with any animal remains. The seventh of the beds can be traced for about 200 feet to the south and 100 to the northward of the rest; here my operations ceased: beyond this the strata are conspicuous, but the intruded trap is no longer traceable on either side. The whole mass is surmounted by a cap or mantle of greenstone forming the ridge on which my house of Balcairn stands, and that running along to the east of the Society's Gardens. It is tossed about and then tilted up about 400 yards to the southward of my house, the crop retiring from the sea shore, and crossing to the westward : to the northward again the beds exhibited by the edge of Sewree Hill, and all across the village of Sewree up to the base of the chert rock (44) on which the fort is built, itself obviously a mass of fused strata, probably of older date and lower position subjected to a much higher temperature than that by which the external crusts of the other beds have alone been affected, the yellow stratified mass under discussion (I shall come to the Sewree Fort chert by and bye) is found in wells all along the back of the village and fort, and so in others along the line of the public road at the base of the hill to the westward. This is surmounted by a mass of trap some 40 feet thick, when a second bed follows this up to the eastward. It is traceable along the face of the hill from the Police Chowkee to where the Parell joins the Sion and Matoonga Road, and here it has everywhere been pierced by wells, and abundance of water found. I am not prepared to say whether the trap has been here intruded or not amongst pre-existing beds, or whether there be two independent formations, or one split in two. The two just examined seem to unite about half a mile further on, where they are either joined or closely approached by that already described as the Chinchpoogly and Parell Hill bed, and passing through the valley of the Gardens. The rock is from henceforth

covered over by a thick mass of marine alluvium. All these beds, especially the lower ones, are remarkable for the abundance of water contained in them ; the outcrop of that next to or beneath the level of high-water mark may be traced for more than a mile by the dampness of the ground, or the grass and rushes that present themselves at the surface, a large growth of which makes its appearance all along the sea shore. In a break during the rainy season after a week of fair weather, when there is not a drop of superficial water flowing, a flow proceeds from them which forms a considerable rivulet from fifty or a hundred feet of outcrop. Of this I shall have occasion to speak more fully when I come to treat on the subject of water. These beds I believe extend over the whole length of the island, and probably into Salsette : they are generally hid under alluvial matter, and the wells in this quarter are few in number, and mostly old.

The Chert Dike of Sewree and Matoonga Hill.

51. Unless very closely examined, the black rock which constitutes the promontory on which Sewree Fort is built may be mistaken for basalt, similar to that of Malabar Hill : a narrow inspection discloses the unexpected fact that it is black jasper or Lydian stone ; it has the same specific gravity as jasper, strikes fire with steel, is luminous when rubbed in the dark, and gives out a strong sulphurous smell ; it scratches glass, and breaks with an uneven conchoidal fracture. It still shows considerable traces of stratification, especially towards the northern end of the mass ; the dip is at an angle of about 25°, or double that of the rocks adjoining, and it is split across into semi-prismatical masses. The Sewree mass is about 200 feet across, 1,000 in length, and 40 or 50 in elevation. It suddenly disappears on the verge of the salt-pans, but a thin vein of it can be traced for nearly two miles to the north-westward, where it reappears in mass, forming a considerable hill to the southward of Matoonga burying-ground, on the margin of the creek betwixt the rice-fields and the salt-pans ; beyond this I have not been able to trace it towards Sion. The rock decomposes very slowly, and affords a poor arenaceous *débris* : its surface yields scarcely any sustenance to vegetables ; the palmyra is the only tree that grows on it, and the short grass which covers it during the rainy season vanishes on the return of the dry weather. It is too hard for a building stone, and too sharp and splintery and difficult to bed for road metal. The heat to which it has been subjected has nearly obliterated all traces of stratification, and of course extinguished every appearance of organic matter. It seems as if it were the remains of beds lower than any we have described ; subjected to semi-fusion, and forced up from beneath. Betwixt this and the island of Trombay is a sludgy creek, here nearly

three miles across, and there is about an equal expanse of rice-fields, before the first rise of the Neat's Tongue is attained : what rocks may prevail under these it is impossible to discover.

Trap and Pseudo-Trap Rocks.

1.—Basalt. 2—Greenstone, upper and lower beds. Porphyry. Amygdaloid. 3.—Trap-Tuffa.

It is in all likelihood to the singular interminglement of volcanic and sedimentary formations that the vast diversity of trappean rocks in the island and its neighbourhood is due. In the topographical description of Bombay I have already given a general account of the basalt and greenstone beds. It is next to impossible to preserve clearness in this matter without some chance of repetition ; these risks I have incurred as less annoying than the obscurity likely otherwise to arise. I have marked off the paragraphs of these papers by numbers, with the view of avoiding this as much as possible.

1. Basalt.—The basalt formation, as already stated, forms a vast sea-wall from Malabar Point as far north as Bassein. The rock is almost perfectly black ; its specific gravity is 2·882 : on the face of Malabar Hill overhanging Back Bay it is columnar, and magnificent masses of basaltic columns present themselves under high-water mark nearly half way between Back Bay and Colaba. They rise from three to five feet above the surface of the sand, and consist generally of four, five, and six-sided prisms, from one to three feet in diameter. On the western side, where the mass appears to be overlain with sedimentary rocks, on Malabar Hill (see Section 8), the columnar form disappears, and the basalt assumes that tuffaceous character generally presented by it when nearly in contact with stratified rocks. Opposite the temple of Mahaluximee the basalt is tabular, and presents us with a regular exhibition of strata dipping at an angle of 8° or 10° SW. On careful examination no trace can be found of a sedimentary origin for these. The mass is generally ill supplied with minerals, in this respect contrasting strikingly with the greenstone of the island. At Versova, as already stated, it is highly porphyritic. (See para. 10.) There is a beautiful group of small-sized basaltic columns near the road betwixt Chimboor Ferry and the village of Trombay, on the island of that name. They are perfectly black, well formed, and from eight inches to one foot in diameter. On the new road to Tanna, near to where the railway crosses it, a fine mass of columnar rock is met with, of a pinkish yellow colour, apparently compact felspar. It rises in masses so regular as to be employed in the railway works without further dressing. It seems to extend in both directions, and probably forms considerable part of the mountain of the "Neat's Tongue"; and it exhibits itself in the opposite direction in the mass of horizontal columns near Powie in Salsette.

2. Greenstone.—The position of this species has already been described (see paras. 12 and 13); and a vast number of varieties of this rock are to be met with in the island. It is usually found in large masses divided vertically from each other by veins of great size, these veins being filled up with red or yellow earthy matter, the results, apparently, of decomposition. Occasionally it is found in globular masses, the globes varying from a few inches to several feet in diameter: they split into coats by decay; the centre portion being generally hard, black, and crystalline. Masses of trap of this sort are frequently found imbedded in a stratified matrix, itself occasionally slightly porphyritic, and where these are exposed to the action of the sea and weather alternately, the appearance presented by them is curious and grotesque in the extreme. (See Plate.)

The upper portions of the greenstone rock are generally hard, brittle, and crystalline, difficult to work, considerably darker than the portions beneath, and held in small estimation by the builder and the quarryman. The rock presents the same general appearance, before being broken, as that just underneath. It seems, when split, as if the superficial melted matter had been suddenly chilled to the depth of three or four feet,—that below having annealed and softened by gradual cooling. The lower greenstone is of a fine rich grey colour: the tint is uniform when first broken, but when exposed for a few weeks to the weather it becomes darker and marked with small spots, exactly as if a slight sprinkling of rain had fallen upon it,—the finer portions of the stone being known to the builder as rain-drop rock. It breaks up in masses of any size short of a cubic yard; and lintels and columns, four or five feet long, can be split out of it by the use of the wedge alone. It is easily dressed with the hammer and chisel, and but for the tint, which becomes nearly black when exposed to the weather, it can hardly be surpassed as a building stone. Near Parell there is a light blue variety of trap of a soft earthy aspect, which easily yields to the stone-cutter; it looks more like hardened mud than volcanic rock. It corrodes when exposed to the weather, and is unsuitable for building purposes, unless under ground. Near the line of railway opposite Parell, the greenstone assumes a dirty olive-brown appearance, and contains immense nests and veins of calcareous spar, sometimes of very great beauty. It is here slightly porphyritic. At the western base of Chinchpoogly Hill the greenstone is of a pinkish ochry hue, and might be mistaken at a distance for Oolite, or sandstone of the coal formation. It closely resembles the compact felspar of Fifeshire in Scotland. As a building stone it blackens in the weather, but is not subject to decay.

Greenstone, Porphyry, and Amygdaloid, are found together in abundence to the north of the Gardens of the Agricultural Society, near the

Baboola Tank, and to the northward of Parell near Matoonga. They abound in minerals, often of great beauty; and wherever, in fact, the trap and stratified rocks approach each other, the character of the former becomes vesicular.

3. Trap-tuffa.—It is difficult to class and describe our trap-tuffas, diversified and irregular as they are, and presenting themselves mixed up in the most intricate manner with the more compact of our volcanic rocks. One of the most prevalent varieties of Tuffa consists of olive greenish or brownish-coloured masses, imbedded in a matrix somewhat darker in colour than themselves. It abounds in calcareous spar in veins and nests. When fresh broken it seems like a plum-pudding-stone of uniform hardness and durability; when exposed to the weather the matrix is rapidly decomposed, and the rock becomes cavernous, like some varieties of lava; the imbedded mass resisting decay while the matrix disappears. It is to be found from the base of Nowrojee Hill (see para. 14) to the Chinchpoogly Salt-pans, and is most conspicuous just opposite the "Mount," and along the north side of the Powder Works compound. Another variety of the trap-tuffa, probably consisting of this, though it differs from it in point of aspect, prevails in the Flats to the eastward of Mr. Dickenson's house. The imbedded masses are whitish, pinkish, greenish, and grey. Where the public road crosses from Sewree to Parell, at the base of Flagstaff Hill, a vast mass of tuffaceous rock, almost white, prevails. It is full of veins and cavities, usually filled with spar. The cavities are of an oval or amygdaloidal form, the longer axis in all cases being from NE. to SW., as if the rock, while still in a soft state, had been compressed laterally from SE. to NW. The cavities are, for the most part, filled with siliceous spars and veins, and coatings of agate and chalcedony. The rock blackens very rapidly with the weather, and its real character is only known when freshly broken. I mistook it, for a while, for common greenstone. Where it is uniform in texture, it is cut up for water-troughs and aqueducts, being soft when first exposed to the air, and hardening afterwards without abrasion or decay,—in this respect resembling Laterite. A purple variety of tuffa, differing altogether from this, is to be found in the hills between Sion and Matoonga. The prettily wooded hill, on the base of which stands the Powder Magazine, is composed of it; and it has here been well exposed to view by the operations of the quarryman.

Further to the eastward, white coloured masses, marked with small ochry spots like porphyry, are imbedded in it; and in detached pieces, on the sea shore, I have found this passing into Laterite. After most careful inquiry I have failed to find the two rocks in contact to determine the fact, which seems more than probable, that they pass into each

other. In nearly all these Tuffas beautiful specimens are found, either of trap which has been disturbed in its viscous state while cooling, or of sedimentary rock which has been slightly fused without becoming either jaspideous or having its texture obliterated. I have not been able to determine which of the two is the correct state of matters, or whether both may not be found occasionally to prevail. The rugged masses of Tuffa are occasionally seen coated with this,—occasionally found running in long thin beds with other rocks; but the trap rocks of Bombay would, of themselves, furnish a cabinet, and the subject of an essay, which could only be properly understood when read with access to the specimens,—a condition of things attainable only to those who have searched every quarry and excavation on the island.

Lines of Junction.—It will readily be imagined, from what has been already stated, that very striking appearances are to be met with at all the lines of junction; and it is matter of regret that so few opportunities present themselves of having these carefully examined. I have already instanced the case at Sewree, where so beautiful an example presents itself between two beds of stratified rock, fusing the upper part of the lower, and the lower surface of the upper beds, into a hard flinty matter. Generally speaking, however, the sedimentary rock has been but slightly altered. At the line of junction, at the Baboola Tank, all the most beautiful of the minerals are to be found, and here cavities and veins of spar are occasionally to be detached in the semifused stratified rock. The trap just under this is full of cavities with veins of from a few lines to half an inch in diameter, running downwards sometimes for several feet, when they disappear; and this holds also along the face of the rock at Nowrojee Hill, and in the wells in the Jail compound, and probably at every point throughout the island where the stratified rock and trap meet together without disturbance. The lower strata of Baboola Tank and Nowrojee Hill are very little affected by the volcanic matter, the carbonaceous matter still remaining in them in abundance. Along the line of railway the two varieties of rock are so confused and intermingled that it is difficult to see where the line of junction occurs, a mass of tuffa intervening which seems sometimes trappean, sometimes sedimentary. It may be laid down as a general rule, that where trap has been forced upwards, and has affected the sedimentary rock, it has itself always been much altered, and rendered cavernous and irregular. This is readily observed at the Sluices and at Breach Candy, where the denudation has left its surface exposed.

SUPPLIES OF WATER.

When it is considered that the annual evaporation over the island

amounts to about 70 inches, or close upon the average of the annual fall of rain, and that for eight months during the year scarcely a shower ever reaches us, the capacity of the island of Bombay for preserving water (adequate to the supply of nearly half a million of people located close together upon little more than ten square miles of ground) must be very remarkable. Our marine and fresh-water formations seem to constitute reservoirs ; the volcanic rocks preventing easy exit, and to some extent cutting them off from the sea. The basalt is nearly destitute of water, although wells are now formed in it in abundance on the eastern side of Malabar Hill, by penetrating through the volcanic rocks to the sedimentary beds below. The greenstone affords abundance of wells, though it is always uncertain where the water may be met with : it seldom indeed makes its appearance till either a stratified rock has been encountered, or we have reached the level of the sea. In the littoral concrete water is found in profusion everywhere, though it is apt to become brackish after blue clay has been passed through. It is probably on this ground in some measure that the sites of the Fort and Native Town were selected : here the marine or the fresh-water formation is found to prevail, and wells are to be met with in hundreds in close contiguity to each other. It is a curious fact, that in this case the water generally rises and falls with the tides. It is only close to the shore where these fluctuations can be observed daily ; but at the distance of half a mile from the sea they are easily discernible at spring tides, occurring for the most part when the springs begin to fall off. I have not been able to discover that the quality of the water is sensibly affected by this, and it would seem to be occasioned by the ponding back of the usual discharge from the shore to the sea. There are scarcely any wells in the island of Colaba ; the only one, in truth, which contains water permanently, is that of the Observatory compound. This is about 30 feet in depth, it extends about 10 feet below high-water mark, and it affords a permanent supply to about 300 people, yielding on the whole about three hundred gallons per day towards the dry season. The water is pure and of excellent quality. The wells around dry up in March. Several wells have been recently dug through the stratified rock, near the Pilot's station, and Colaba Church, which are well supplied with water. Others have, of late, been excavated through the trap near the Gun-carriage Manufactory, which promise to be productive. The Esplanade, Fort, and Native Town abound in wells which are well supplied with water. Along the line of the sea shore fresh-water is to be found all the year round, within 50 feet of high-water mark and 10 feet of the surface ; and the occupants of tents may always supply themselves by making a hole a few feet deep, and lining

it with a couple of beer barrels. By far the finest reservoir is Baboola Tank, near the Grant Medical College, originally a quarry and still from time to time deepened and enlarged for the sake of the stone it supplies. It is 1,050 feet in length, and 450 feet across, and it contains, when full, nine million cubic feet of water. Within a couple of hundred yards of this, a magnificent tank, thirty feet in depth, and one hundred and fifty feet each way, has been excavated by Sir Jamsetjee Jejeebhoy, expected to contain 400,000 cubic feet of water. When almost completed it was discovered that a great rush entered it near the bottom, and the water so brackish as to be useless except for bathing purposes, containing half the salt of ordinary sea-water, though at a distance of more than half a mile at the nearest point from the sea. It is probable that this may either be built out or got rid of by other means by and bye. It is a singular fact that it should appear in such profusion, evidently not coming directly from the sea from its modified degree of saltness, yet, from its uniform flow at the driest periods of the year, being derived apparently from some ample but tainted source of supply. Nearly all the wells in the Flats are more or less brackish, as may be expected from the amount of salt with which the clay around is impregnated. From Matoonga to Sion, over a large tract of ground, water is generally to be procured at a depth of from 10 to 25 feet; and it gives us a sad view of the neglect of agriculture on the island, that, with a rich soil and a profusion of manure and water, the land should remain barren for eight months of the year, the cultivator being content with a single rice crop raised during the rains. The vegetables and fruits in most demand in Bombay are all brought from Salsette, or the islands to the north of it,—reversing in this way the usual economy of countries where agricultural productions of difficult transport are raised in the neighbourhood of the point of consumption; the rice and grain, which may be carried at a moderate charge, are grown close by, while vegetables are brought from the interior, and the state of matters prevails up to the very enclosure of the gardens of the Agricultural Society. A regular register of wells is kept by the Board of Conservancy, and a return of their condition made periodically to the Magistrate of Police. Some years ago a chemical report on their waters was prepared by order of the Medical Board; and an extension of this, so as to include all the wells of the island, would form a very valuable document.

Calcareous and siliceous spars are the most abundant of the minerals found in Bombay, some of the latter being found in great beauty in quarries near the railway, near Parell, in Baboola and Paedhonee Tanks in the Native Town, of which I have been fortunate enough to obtain

a magnificent collection of minerals, of the Zeolite family, the finest of which were laumonites of most singular beauty. The crystals of the different minerals often lie over each other, layer above layer; in one instance a specimen of perfectly transparent selenite was found in a cavity, in trap partly covered over with crystals of calcareous spar and apophyllite.

With the exception of laterite (referred to at length hereafter*) I am not sure I can venture on enumerating any of the exogenous rocks found in Bombay as strictly speaking transported. Granite, quartz, and limestone, in a variety of forms, are to be found on our shores, but the great bulk of them appear to have come as ship ballast; and I have found none so situated as to warrant the assumption of their deposit there by natural causes.

Papers on the Subject.

An Account of the Geology of Bombay was published in 1836, in the Madras Literary Journal, by Dr. Thompson. It is meagre and imperfect; and he makes no mention of the stratified rocks which form so important a characteristic of this part of the Konkun. There is a paper by Dr. Lush, in the Transactions of the Bengal Asiatic Society for 1834, on the Geology of the Northern Konkun, in which there is a short notice of Bombay to be met with. He assumed, as has already been seen, that it was a single mass of stratified rocks, and that this lay above our traps. Mr. George Clark gives, in his notice of the geology of this neighbourhood, a short but clear and correct outline of the fresh-water formations of the island; and this is all of which I am aware that has been published upon the subject. The present paper owes its origin to some experiments to reclaim the Flats, in which I was engaged from 1846 to 1848, and of which an account was desired by the Court of Directors; and to the excavations on my own grounds in preparing a site for the School of Industry at Sewree. The spectacle of some thousands of acres of fine promising ground, just in the neighbourhood of half a milion of people, with an unbounded supply of manure and fresh water close at hand, seemed so singular that I determined to make the experiment of washing out the salt which rendered the Flats unproductive, and to endeavour to bring them into garden cultivation, introducing in the course of these works the use of the windmill, a variety of implement promising to be of inestimable value to us, but utterly unknown in India. For these ends I obtained a grant from Government in 1846 of a space sufficient for the experiment, and enclosed

* Trans. Geograph. Soc. Bombay, vol. x. p. 231.

it with an earthen mound close by the Town Drain, from which I proposed to draw water during the rainy season to wash out the salt, and liquid manure during the rest of the year, with water as might be required to fertilize the ground. Difficulties presented themselves in the way for which I was not prepared ; I was less successful in the windmill machinery than I had expected ; and the time I could devote to these matters was so exceedingly small that nothing conclusive had been done when it was resolved to admit the sea water into the Town Drain to carry off the nuisance it occasioned, so as to put an end to all my expectations of success. The Court of Directors had called for an account of the experiments ; the explanations of the source of my expectations and the grounds of failure could not be made complete without a Section on the Geology of Bombay. This was forwarded through Government in June 1850. As I had heard nothing of its having reached its destination, I availed myself of the unusual advantages presented by the droughts of April and May 1851, and the works then in progress, to correct and enlarge the paper and to cast it into its present form. My friend, Mr. Henry Carter, has, it appears, been meanwhile engaged in a similar enterprise. I was not aware of his having written on the subject till his paper was laid before the Asiatic Society in December ; and although I have no doubt of its great superiority, in paleontological and mineralogical matters, to anything I have produced on the subject, my conviction is that the views we are likely to have taken are so different that both papers may prove acceptable in the Transactions of the different Societies of which we are Secretaries respectively. His Essay, in all likelihood, deals with scientific and speculative inquiries, while mine treats of economic geology. I have been, purposely, as minute as circumstances permitted, deeming it expedient that everything in the shape of fact, referring to local phenomena, however trivial, should be placed on record in the transactions of a local Society ; leaving the reader, afterwards, to select those things that are important from those which may appear more immaterial. To the English reader it will appear singular that, after all, so little should be known of the geology of this locality—so limited, yet so interesting. It must, however, be remembered, that though the population is large, the number of geologists is small ; that those who have most leisure at their disposal are not always inclined to employ it profitably ; while those who would make the most of their time, had they any to spare, are occupied by the duties of their professions. The climate, too, only permits of a few hours in the morning or evening for out of door occupation ; the rainy season for four months seals up the surface of the earth from observation altogether ; and unless sections be made while the excavations are in

progress, during the months of April and May, the opportunity is lost by the exposed rocks being encased in building, or concealed by *débris* or vegetation.

Although we have been digging wells, making cuts and excavating foundations, for more than a century, yet no record appears to have been ever kept of the material encountered; and the Board of Conservancy is, at present, as much in the dark as the original Portuguese conquerors of what material they are likely to meet with when they commence operations in excavating a well. It is to be hoped Mr. Carter's paper and mine will, between them, furnish a foundation, at all events, for the labours of future geologists. I am willing to begin and to acknowledge the imperfections of my performance, rather than run the risk of waiting until I should be able to make my task complete.

I have stated that some of the most interesting sections were obtained while preparing a site for the School of Industry at Sewree; and I trust I may be pardoned if I mention, with no small degree of gratification, that the colouring of the drawings has been all executed by my convict pupils.

The Trap Formation of the Ságar District, and of those Districts Westward of it, as far as Bhopalpur, on the Banks of the River Newas, in Omatwara. By Captain S. Coulthard, of the Bengal Artillery.

[Reprinted from the Asiatic Researches, vol. xviii. p. 47.—1829.]

A general idea of the number of sandstone hills, rising through the trap formation of the district about to be described, may be formed from the number of villages; for although a few villages may be seen situated on the slopes of trap hills, the natives, as far as possible, have avoided placing their habitations on rocks of this formation, and there being fully as many sandstone hills without villages, as trap with them, it may safely be said that there are as many isolated patches of sandstone in these districts as there are villages.

At Panchamnagar and Satpárah, places marked in the accompanying sketch, there is the lias,* and about nine miles west of those places, or at Sanwa, the trap and sandstone. The same may be said of Pattaríya and Garakota, on the right hand, and Shahpur, one march on the left, or westward; and then, if a line be drawn between these places as respectively mentioned, leaving the nameless rivulet as it occurs between Shahpur and Pattaríya, in the lias, and also continue this line southward to the red sandstone hill, which overhangs Tendukaira, in the vale of the Deorí, there will be a tolerably correct eastern boundary given to the trap formation of Ságar.

The vale of the Deorí is of an older formation than either the lias of the Hattah district or the sandstone subjacent to the trap of Ságar.

That red rock, which has been alluded to as skirting the Deorí, near Tendukaira, has its accompanying trap hills, and these, in their general direction, bend their course to Hasanabad; indeed, at Sírmow, or soon after passing south of that place, the road from Ságar to Hasanabad descends this trap range, and afterwards continues at their feet, on the

* Probably the limestone of the "Intertrappean Lacustrine Formation." See my "Summary of the Geology of India," at the end of this volume. The name of "lias limestone" was provisionally given to this formation by Captain Franklin (As. Res. vol. xviii.), in his lasting record of the Geology of Bundelkhand, &c., where he states, at p. 39, "it is a mere plastering over the surface of the red *marle* or *sandstone*, and I should doubt whether it ever attains the thickness of a hundred feet."—Ed.

south side, the whole distance to Hasanabad. Let it be added to this, that the road for fifteen miles south of Hasanabad, or as far as Petraotah, is on the alluvial matter of the Nermada, a deep black basaltic mould, and that at Petraotah a hilly country again occurs, consisting of primary rocks, contingent on the granite of Shahpur, Nímpání, and Bitúl, and then there is a definite bounding line on the south.

If the cantonment of Bhopalpur, on the right bank of the river Newas, be taken as a point, and a line be drawn from that point to the Nermada, so as to pass between Sultanpur and Dewas, such line will cut through the eastern part of the trap formation described by Captain Daugerfield, as that officer marks both those places in his sketch; indeed, that which is under description by me is a mere continuation to the eastward of the newest flœtz trap formation, named by that officer as occurring in the upper plains of Malwa, or, to speak still more correctly as to direction, it is a shoot up north-eastward from it.

With regard to the northern line of demarcation, I cannot be so satisfactory and clear. If a line be drawn from Bhopalpur to Seronj, it will pass through the formation under review, but as to how far this formation extends north of such a line I have no precise information. The Maltoun Pass is of sandstone, and I believe this rock ends somewhere between the crest of the Pass and the village of Naret, not far removed from its northern foot. The granite is at Tirí. An iron ore is worked to a considerable extent at a spot intermediate between Dhamúní and Marowra; Dhamúní has the trap and sandstone; and the trap ceases five miles and a half south of Hírapur, whilst the bare sandstone, freed from any overlying mass, continues until it may be seen resting on matter incident to the primary rocks, at Hírapur, and where, too, it ceases entirely. Nearly in this direction will be the northern limit of the trap formation, as laid down in the accompanying sketch, but much confidence is not to be placed in it; the boundaries, however, to the east, west, and south may be offered as sufficiently accurate.

It is eighty-four miles from Bhopalpur to Bhilsa, and seventy-two from Bhilsa to Ságar, and twenty more bring us to Shahpur: and this line, though not a straight line, is sufficient to give a general idea of longitudinal extent. Hírapur, in the northern quarter, cannot be less than seventy miles distant from the southern boundary given to the sketch; and the whole of this extensive area is occupied by the newest flœtz trap formation of Werner, subjacent to which is the new red sandstone, shooting up frequently from below through the overlying rock.

It is a hilly tract throughout, but it may be better understood if it be said that at Ságar, in its neighbourhood for eight or ten miles around, and also in every part south of Ságar, within the prescribed limits, and

as far west as Hasanabad, may be seen ranges of low hills extremely clustered, though always detached, bending about in their short course towards all points of the compass, and thus forming valleys of every conceivable form, though not commonly of any great extent, and never difficult of access. But if the view be extended beyond the neighbourhood of Ságar, towards the east, or the west, or the north, expanded valleys will gradually meet the eye, whilst the hills recede from it, sinking in the horizon as they surround valleys further removed from Ságar, until these valleys are enlarged into extensive undulating plains, studded over with isolated trap hills, occasionally of a conical, commonly of no determinate form, whilst ever and anon a short range of the same, deviating little from a straight line, will have its beginning and its ending within view.

These valleys and these extended open plains are everywhere composed, near the surface at least, of a trappean or basaltic mould, blackish in colour, which reposes either on a bed of basalt or on a bed of compact wacken. This compact basalt, or compact wacken, is either of an uniform ovate form, or else it is in angular pieces of middling size; and underneath these, as their occurrence may respectively be, lies an amygdaloid decomposing and decomposed, and which, as a retentive clay, keeps up the water near the surface, and it is so met with throughout this tract.

As to the trap hills, there is no occurrence of a bold bluff escarpment belonging to them, their sides and ends are always sloping and rounded, and, as far as the angle subtended from the summit is concerned, of easy ascent. Their surfaces are thickly strewed over with masses of basalt or wacken, imbedded in a basaltic or wacke clay, and differing only in size and form in different places in a trifling degree. From 120 to 150 feet above the edge of the contiguous vale, may be said to be the general height of those that rise above the rank of swells and knolls, whilst a hummock, a cone, or something of a truncated cone, occurring in their otherwise even outline, and which serve to characterise them from their sandstone companions, partially increase the elevation.

The sandstone rock is very prevalent, as a mere mound or rise, constantly having a village upon it, and situated often on the plain ground, oftener on the edge of the plain ground, with a trap hill partly resting on it. In particular parts of the country, however, ranges of sandstone hills occur equally, though never exceeding in height and extent of range those of the trap, whilst they are to be easily distinguished from them by their general evenness of outline; by their having vertical or precipitous escarpments at their ends, and on their sides to within 20 or 30 feet of the top; by the fallen masses lying about; by often sharply-defined, castellated, and mural appearances on their summits,

and, in short, are to be distinguished by all that which has been remarked of them as exclusive, when occurring in other countries. They never appear interstratified with any other mineral, when they occur in the tract of country under review.

And these swells and hills of sandstone and of trap, most particularly the former, may often be observed sterile and bare, showing nothing but some coarse grass during the season of the rains, which gives to them, at that time, a tinge of green ; but the vast majority of them are ever thickly clothed with vegetation, consisting of plants, and shrubs, and forest trees of stunted growth, in particulars only differing from those of constant and everywhere occurrence in India, and which have often been numbered and described. And lastly, the flat and compressed surfaces of both kinds of hills are often of considerable breadth, and on the summits of the trap hills, not those of the sandstone, more especially in the angular parts of the trap hills, as they bend about, may be seen a patch or cultivated spot.

With regard to the general level of this land above the sea, I may observe that there is a peak shooting up from a trap range to the eastward of Raisen, which attains an elevation of something more than 2,500 feet ; but the hills of Raisen are much less, so also is the sandstone range of hills on the north bank of the Nermadá at Hasanabad. Ságar, upon the whole, is the highest part in this tract. The centre of the cantonments at Ságar is 1,983 feet above the level of the sea by the barometer; and the hill at the Mint of Ságar, which is about a mile from the lastnamed point, is something more than 2,300 feet by trigonometrical calculation. I have before remarked that Ságar and its neighbourhood is a confined hilly tract, and that towards the east, and the west, and the north, the country opens; and it is, in fact, taking Ságar as a radiating point, in those directions that the land opens that the general elevation of it above the sea decreases; but not so much westward or towards Bhopalpur, as the general elevation of the upper plains of Malwa is 1,650 feet, and Omatwara, in which Bhopalpur is situated, belongs to those plains; neither is it so much towards the lower lias formation of the Hattah and Garakota district, or eastward, because the elevations there are, in general, about 1,500 feet. It is in the northern quarters that the principal and a rapid diminution in height is to be observed, for the Moltoun Pass, nearly due north of Ságar, and six and thirty miles distant, is only 1,000 feet above the level of the sea by trigonometrical calculation ; Seronj, to the westward of north from the same place, is 800, and Hírapur, to the eastward of north, between 1,000 and 1,100 feet by the same calculation. From all this it is to be inferred that the elevation about the central point of Ságar is from 1,800 to 2,500 feet, and that in a northerly direction the land declines considerably,

and much more in that direction than it does towards the east or towards the west. In addition, if it be observed that the primitive range skirting the alluvium of the Nermadá, south of Hasanabad, was found to be on a general equality as to height with the trap and sandstone rocks of Ságar, whilst the granite range of Bundelkhand, on the northern limits, is at least 1,000 feet lower than those rocks of Ságar, a point nearly midway between the two-named primitive ranges, all is said, it is hoped, that need be, to assist the idea as to what is the general elevation above the level of the sea of the trap and sandstone under review.

There exists so strong a family likeness between all the trap rocks of this formation, that it may safely be said, was chemical analysis resorted to, a nearly similar result would, in almost every case, be obtained. It is always everywhere an earthy homogeneous deposit, by which it is to be inferred that there does not occur in it any rock of a definite, or nearly approaching to a definite, crystalline structure; neither a coarse-grained basalt will be found, nor a syenite; nor a greenstone, showing distinctly its constituent simple minerals; nor is there, indeed, either a clinkstone or claystone. It appears as a closely allied family of basalts of a very fine grain, of wackens and amygdaloids; all others, of the long list of trappean rocks, may be thrown out of consideration, as of no alliance and of no occurrence here.

No. 1. Of the few varieties there is one basalt which has been said* to be similar to the Rowley Rag, and it certainly does agree very closely with the description given of that mineral. Its colour is greyish-black; its lustre is slightly glimmering, and it has a flat conchoidal fracture, and is difficultly frangible. It is not here the rock of most common occurrence, but I name it first, and mark it No. 1, because it is the hardest. It does not rise above the surface, but occurs in beds where the masses are of an uniform, egg-shaped figure, perhaps a foot and a half in their longest diameter; or it occurs in beds, where the masses are angular pieces or cubes disfigured, not much exceeding a foot in measurement any way, and closely set together without cement. It seems to be little liable to external decomposition, and its surface, which is smooth and entire, is coloured a yellowish white.

No. 2. There is another basalt differing little from the last, except that it has not the same tenacity, and its colour is soot-black. It occurs only in angular pieces. I mark it No. 2.

No. 3 is another in colour like the last, but still softer, and which splits, with a moderate blow, at natural joints, into small four-sided prisms, coated with a bluish coating, like that often seen on newly wrought iron. It is in the mass amorphous.

* By Dr. Voysey, I believe.

No. 4 is a five-sided prism. When the bed of a rivulet or river is composed of angular pieces of basalt or wacken set together in a pavement-like form, the surfaces, exposed to the double effects of intense heat and moisture, will appear cracked into a variety of prismatic forms, and occasionally it will appear such as No. 4.

All these rocks seem to be, though not wholly, yet essentially composed of an intimate mixture of felspar and hornblende in an earthy state; and the latter, or hornblende, is the mineral that characterises all the harder kinds, whether compact or amygdaloidal, whether they are basalts or wackens, for their colour is black, or black only slightly modified. The structure is always massive,—a laminated specimen could not be obtained.

But the principal rock throughout this formation is that represented by No. 5. It is what is termed a compact indurated wacken, in colour black, with a very distinct brownish tinge. When first fractured, its surface has a much more glimmering appearance than the basalt, but, unlike the basalt, exposure to the atmosphere soon changes its surface into an earthy dirty whitish colour. It is often very tough, very refractory under the hammer, but its fracture is flat and dull, not sharp and splintery, or approaching to the conchoidal. It occurs in pieces, in length, breadth, and depth pretty nearly the same, a foot in measurement, and which are set closely together, so as to form something like a stratum in the hills, or in the valleys as the base of the basaltic mould; and it is also the predominating variety in those hills which are of such constant and general occurrence, consisting of large rounded and angular masses, thrown up together in the utmost confusion, with very little clayey matter intermixed; and, lastly, it may often be seen abstracted and alone, in something like large uniformly ovate masses, having a brownish and wrinkled exterior, and imbedded in a sombre reddish-brown clay. No. 5 is taken from a hill of the last kind.

No. 6 will exemplify the same where set as a stratum.

No. 7 is also the same kind of wacken, but it is decomposing with a nucleus of undecomposed black matter, and the superficial and decomposing part is a light yellowish brown; further stages of decomposition might easily have been shown to where the whole matter is changed to a greyish colour, and chips off into fragments like pieces of a small bombshell, or to where the whole mass is nothing but a soft easily workable clay, showing, however, still the curved lamellar structure, and what it once must have been.

No. 8 has an aspect much resembling basalt properly so called, but its fracture is flat and sluggish.

A cellular or honeycomb mass will often occur intermixed with any of the foregoing, the cells of which are externally empty, and internally

filled with powdery whitish oxide of iron, which immediately falls out when the stone is fractured,—such is No. 9.

No. 10 is wacken, with much olivine interspersed.

And No. 11 has something of green earth, and something of olivine in specks and splashes.

No. 12 has rather more of a bluish grey than a black caste, probably from the felspar rather exceeding its usual proportions.

It is much to be wished that the term basalt could be extended so as to include all those rocks named wackens, for, although there is some slight diversity of fracture and frangibility, and some little variation in colour, yet a difference in name seems quite uncalled for in regard to them, and only calculated to mislead. However, thus much may be said, that those rocks in this list named basalt are strictly compact,—no casual mineral will be found imbedded,—whereas the wackens, on the other hand, whilst they are sufficiently compact to exclude any other term than compact, are seldom quite entirely so. An accidental mineral of the kinds incident to amygdaloids may almost always be detected in them, and this too, together with the similarity of paste, serves to connect them with these amygdaloidal varieties, which, as elsewhere in trap formations, here most commonly occupy the lower positions.

No. 13 is an amygdaloid which has been thought to resemble the toadstone of England. It has a black homogeneous paste containing chalcedonies, calcareous spar, and green earth. The former are often geodes coated externally with calcareous spar, and internally lined with minute crystals of quartz, with calcareous spar filling up the cavity. Where green earth occurs in the same cell with siliceous crystals, the latter appear in a decaying state. The size of these imbedded portions do not, in general, exceed a nutmeg, although the chalcedonic geodes, &c. are sometimes a little elongated to the extent of three or four inches, and their sides are compressed.

No. 14 has the same paste as the former, though softer, and, excepting green earth, has the same imbedded minerals; and when these are of a moderate and usual size, very pretty specimens of the whole rock are afforded, but, in general, this variety of amygdaloid envelopes very large-sized portions. A cylindrical geode of amethystine quartz was found, measuring thirteen inches in length by two and a half inches in diameter. It was coated internally with beautiful quartz crystals, with calcareous spar, as stated in the previous specimen, filling up the cavity, and this mineral also coated the geode externally, and was seen much in splashes in the paste proximate to the cell. As regards these amygdaloids, it would seem, in proportion as the contained mineral is large, so is the containing matter soft and friable, though still retaining its colour, a black when fresh fractured.

No. 15. Paste as before, enveloping green earth, chalcedonies, and zeolities, the latter predominating.

No. 16 has a paste of a bluish grey colour, and appears almost completely saturated with calcareous spar; though much softer than any of those previously mentioned, it possesses greater induration than Nos. 17 and 18.

No. 19 is an amygdaloidal mass, consisting of innumerable pea-form nodules of calcareous spar, cemented together by a thin cement of basaltic or wacke clay of a light colour.

No. 20 is fully engrossed by minute crystals of zeolite, excluding from the paste any other mineral.

No other trap rocks than those I have mentioned are here of obvious and constant occurrence; at least, if any other varieties exist, I saw them not. With regard to the simple minerals contained, calcareous spar is the most abundant; green earth, chalcedony, and quartz are also very prevalent, but the zeolite minerals may be quoted as scarce. Well-defined jasper is rarely seen, but something above an indurated clay, what may be termed semiformed jasper, is of constant occurrence, so is hornstone; and both these last are to be found independent, but they are more generally lying contiguous to the limestone, from which they are derived. The iron clay, so easy to be met with everywhere, would hardly ever satisfy the mineralogist, for it is for the most part amygdaloidal, and not a simple mineral. It sometimes rises to the rank of a poor earthy red ore, and it is as such worked near Barseah, near Raisen, and at the source of the Dasaon, &c. Olivine throughout is very common; but I have never procured either a crystal of hornblende or of augite.

But to the trap—not to the sandstone—belongs a hard white earthy limestone, harsh and gritty to the feel on the fresh fracture, and in which, rather sparingly, are imbedded small rounded particles of calcareous spar of a yellow colour. It belongs to the trap, and it is, moreover, ever attendant upon it throughout its range. Near the surface, or where it is in immediate conjunction with other matter, it may be found varying in colour, and varying in the quantity of spathose matter. Very frequently it will be of an ash colour, and the spathose particles, which are white and thickly set, form the majority of the mass. Other specimens are reddish, brick-red, deep chocolate, or brownish-black; others again might be produced, of which it would be difficult to say whether they were limestones or amygdaloids; but always in proportion as it is coloured, so is it the more clayey, gritty, and impure,—more affected by foreign matter than that substance which I have described as the principal and characteristic rock.

This limestone rock is never found in the valleys; it is confined to the

hills and low swells, and generally forms the basement stratum in them, ascending somewhat above the level of the contiguous valleys. A stratum of this kind is always sufficiently obvious in a hill possessing it; for along its sides, or at the ends, either a white patch, mouldering by the weather, immediately catches the eye, or large, rolled, and angular pieces stand about, of a greyish colour, and very discernible from the blacker trap; though the continual line of the stratum, where it juts out to day, is not easily to be distinguished, the knobs, and exposed parts being generally covered with a blackish crust, and also intermixed with masses of indurated trap, and other more earthy matter, *débris* of the same, slid down from above. A white patch of this limestone, mouldering by the weather, is the source from whence come the particles of *kunkur*, found intermixed with the black basaltic earth of the neighbouring valley, in such proportion as to add increased fertility to it; and if a rivulet meanders through that valley, and such is generally the fact, patches, made up of aggregated particles of the same, will here and there be found, and this it is which the native families pick out and work into lime. Where the grey-coloured, large, rolled, and angular masses occur, there it is that a hornstone and jasper are to be found, though not both together in the same spot. The introduction of silica is of course the cause of the wholeness and induration of those masses, which easily effervesce; but endless gradations are to be seen between these and the two other minerals just named. If indurated clay and semiformed jasper are the derivations, the colour of this will, for the most part, be deep yellow; if green earth is the constituent of a neighbouring amygdaloid, the specimens will offer two colours, green and yellow, or yellow freckled with green. The hornstone varies much, from deep chocolate to straw yellow, from flesh-coloured to nearly white. The flesh-coloured hornstone, or chert, and the specimens showing the limestone passing into this flesh-coloured hornstone or chert, found at Bapyle, about seven miles westward of Ságar, resemble exactly the same substances brought from the lias of the Hattah district, or eastward of Ságar; and this, together with the yellow fragments of limestone, of a tooth-like form, and somewhat dendritic aspect, also found at Bapyle, as well as elsewhere, is the fact that has much tended to increase the idea that the limestone of the trap of Ságar, and districts adjacent, is the lower lias half calcined and disguised by the trap.

Some specimens of that which I have called the characteristic limestone will not effervesce at all, whilst others do so but very weakly; but still oftener the acids take effect with sufficient briskness. Often the stratum of limestone is broader than the trap, which reposes upon it; and upon the mounds, and swells of limestone at the foot of the hills,

occasionally will be found a spot solely occupied by innumerable small fragments of spathose matter. These fragments are of a striated and radiated structure, and appear as if they had been purposely broken by the hand, and clustered together to the exclusion of any other matter; however, it must be added, that some specimens of this species of spath are seldom wanting wherever the limestone rises to day; indeed, the crystallised matter of this formation, when not imbedded in other substances, seems mostly to present itself with either a fibrous, striated, or radiated structure, and it is in its nature not pure and translucent.

A calcareous cement, in these trap valleys, and near a streamlet, is often found forming trap-tuff, that is, found uniting small pisiform specimens of all the rocks incident to this tract into a mass, or bed of sometimes considerable induration, the surface of which will attract the eye by its rusty iron-brown aspect, and its sterility.

It remains for me to describe the sandstone underlying the trap, and so very often rising up through it, in the shape of hills and swells. It is in no instance that I have seen interstratified with any other rock. Red marl, or clay, is sometimes to be seen alternating with it, in thin streaks, resembling the same rock under the lias of Hutta, &c. Galls of clay, or lithomarge, may frequently be found imbedded; and as to its colours, what elsewhere has been said of the same rocks in this regard occurs here, namely, they vary from a dark chesnut or chocolate, through red, reddish, and salmon-coloured, to nearly white. Massive kinds often show two colours—seldom more than two, and these two colours are a greyish-white and a deep chocolate, or it is a deep chocolate speckled with white spots. The slaty varieties, on the other hand, are exhibited clouded, streaked transverse to the structure, zoned, green, brown, red, ochre-yellow, orange-yellow, &c. &c.,—are, in fact, seldom exhibited, otherwise than with much diversity of shade and colour, except, perhaps, a green variety. These slaty kinds are extremely micaceous, and the colours in the streaked varieties above alluded to change at the line of cleavage; and, lastly, the eye never perceives any inclination worth mentioning, or variation from the horizontal position, either when viewed in the whole alluding to their general air and look, or when viewed in any part as regards the constituent, angular, and tabular masses of these sandstone rocks. All this leads to the decision that the rock in question is the new red sandstone, and the lower division of that formation as defined by Macculloch, otherwise the principal compact rock is by no means so tender as to be unfit for economical purposes. On the contrary, it is a hard, glassy, splintery substance, evidently composed of fine grains of sand, held together by a solution of silica, and assuredly not a free working stone, though it is squared, with some difficulty and failure, into appropriate masses, and everywhere used as the com-

mon building material. Varieties of less frequent occurrence, and differing little from the principal rock, except in being somewhat softer, are hewn for the architectural purposes of the small temples of worship, and chiselled to produce alto-relievo representations of the various Deities, &c.

The trap mantles round at the feet of all these sandstone hills, and renders them isolated as far as regards the surface of the land. The angular masses composing the hills differ much in measurement, whilst they are set together very closely in a horizontal position; or, if any remarkable interval exists between the masses where the vertical separation occurs, it is generally empty, no clay, no *débris*, nothing will be found. The massive bi-coloured blocks are not confined to any particular spots, they are casual everywhere; and the same is to be said of the slaty species, for a nest of this latter will now and then be seen with an immense mass of the common characteristic massive kind resting upon it; though at Maswásí, Ṣatgerh, Garspur, Bhilsa, and Narsinhgerh, there would appear to be a continued stratum, occupying a place in the whole line of the hill at each of these places. Often at the ends of the hills there is a bluff, rugged, perpendicular escarpment, and, of course, the rock is exposed from the base to the summit. Oftener there is a very easy slope both at the ends and along the sides from the edge of the trap, that is, the base of the hill, to within 20 or 30 feet of the top; from this the rock continues upwards precipitous and rugged, and the crest is gained only after difficulty and search for particular points. The matter that gives the slopes described is merely and exclusively the *débris* of the parent rock; and the vegetation which clothes the surface springs up between the fragments, time and the elements having worn off matter from those fragments, and so generated something of a soil beneath them.

I might have mentioned before that the principal quartzose sandstone, that which I have described, when first fractured and brought from the quarry, is of a beautiful sky-blue, which soon by exposure turns to such as the specimens show it, a salmon-colour or flesh-colour, or slight modifications of these. The slates of Satgerh, if they split off less than two inches and a half thick, are too friable, and are thrown aside as waste. Some of the quarries are already abandoned, and the whole appear to have been commenced about half way up the hill, on the crest of the more sloping part, at the eastern end, and thence along both sides to some distance. A slow fire of stout sticks of green wood is placed on the inner side of the table worked, which at length cracks it down about a foot, and, as a whole, it is then tapped into parts of the required length and breadth for paving eaves of houses, &c. It is the slates of Maswásí that answer for roofing; these are generally something better than half

an inch thick, and they are flexible, that is to say, the effects of the sun warp them, so much so, that if put on with a cement they crack and break. Finally, I may add, that a thin covering of refuse and stony stuff crowns the summit, resting upon table-shaped pieces, which repose on larger cubic masses, and thus far downwards the aspect of the whole is bare, rugged, and either perpendicular or overhanging at the sides and ends of the hill. To the cubic masses succeeds a stratum of slate, after which again the massive in large blocks; both these covered by the *débris*, which I have spoken of, as forming an easy slope to the sides and ends of the hills, easy as to the length, but of troublesome ascent, because of the looseness of the component material. Such is the hill of Satgerh, surrounded on all sides by the trap, and such too is the predicament of every sandstone hill throughout this trap formation, with exception to a continuous stratum of slate, which, of course, is comparatively of unfrequent occurrence, though small nests, or patches of it, will always be found in almost every sandstone hill exhibited through the trap.

A conglomerate or breccia, having an argillo-calcareous paste, coloured red by the oxide of iron, and enveloping angular pieces of various sizes of the proximate rock, will often be found at the feet of these isolated sandstone hills, if a streamlet winds its course near; or there will be at such points pudding-stones and breccias, varying in colour and aspect from this described; and occasionally, too, in having an argillo-siliceous instead of a calcareous paste; but neither these nor that just described are of any geological importance whatever, and the same may be said of the trap-tuff.

Whether a well be sunk in the trap or the sandstone, the water is always found at a very easy distance. It may often be come upon, even during the dry season, within three feet of the surface in the valleys; sometimes it will be so low as 25 feet, whilst the medium is about 12, and from that to 15. It is the toadstone that limits the depth if the well be excavated in the trap;—the sandstone is of itself sufficiently consolidated and retentive if the shaft has been sunk in it. If the edge of a hill or swell is pierced, of course the vertical height of such swell or hill must be added to the measurement just given; for instance, the well on the edge of the hill at the Mint of Ságar.

The surface of the slope where this well was opened was thickly strewed with large black wacken boulders, and these continued for some little depth below the surface, enveloped in a dark, reddish, rusty, ferruginous wacke clay, succeeded by a bed, 10 or 12 feet thick, of large angular pieces of a deep chocolate-coloured basaltic hornstone, underlaid by a bed of yellow clay, which yellow clay or lithomarge formed, indeed, a sort of coating or lacing to the superincumbent hornstone.

To these followed a stratum of limestone, similar to that of the Cantonment wells of Ságar, resting upon the softer amygdaloids, which I have numbered. In these amygdaloids the water presented itself at a distance of 47 feet from the surface.

The following are the strata met with in a swell in the Cantonment of Ságar on a swell of trap :—

	Ft.	In.
Rubbish and soil	1	6
Indurated wacken, in angular pieces of uniform arrangement..	10	6
Wacken, changed by calcination into a species of puzzalana..	1	0
A thin black streak (rather remarkable), a vegetable deposit, changed by calcination so as to disintegrate and fall to pieces in water	0	3½
A white, hard, earthy limestone, sometimes effervescing weakly with acids, sometimes not at all ; small yellow specks of calcareous spar are seen in it, and, occasionally, a concretion of a purplish grey colour occurs, violently affected by dilute muriatic acid	23	0
Wacken, with fibrous carbonate of lime, and ditto in veins with chalcedony	7	0
An amygdaloidal wacken similar to the toadstone of England.	6	0
Total to the water..	49	3½

The difference in depth that occurs in the valleys before the water is attained arises from the form of the valleys being always concave, and the basaltic black mould deepest in the central parts. The soil, whatever is its occurring thickness, must be pierced, and also the indurated wacken or basalt, whichever it may be, and then the water is found resting on wacke clay or amygdaloid. The sandstone keeps up the water even to a higher level than the amygdaloids of the valleys ; and the occurrence of either of these rocks forms all the phenomena of water in these districts.

Proceeding from the centre of the Cantonments of Ságar, and travelling westward, you descend and cross the flat, which is the general parading ground, and at its confines you come to a small isolated rise of sandstone on your right, on which is built a *busah* godown and a bungalow, and on the left a ridge, a branch from the sandstone forming the basin of the Ságar lake ; passing the town, and a little beyond the wall on the western side, a rivulet is crossed ; then the road leads, by a gentle ascent for two miles, to a low swell of trap, through a gorge or opening, in which you enter the valley of Bapyle, and find a trap range close on your left, and one of sandstone on your right, five or six hundred yards removed, forming the southern and northern sides of the valley. This

valley is the practice ground of the Artillery, and must be at least three miles in length. At the western extremity another range of sandstone occurs, either end of which range is within view, though it is elongated N. and S. to some little extent. A high rugged romantic hummock, capped in a picturesque manner, with a disproportioned mass resembling a rocking-stone, is joined by a low neck to the main sandstone range here, and partly on the declivity of the main sandstone, and partly on the low neck, is situated the village of Bapyle; opposite the hummock, only separated by a little broader space than is occupied by the intervening road, the trap range, the southern boundary of the valley, comes to a point, where is seen the limestone, and the flesh-coloured cherty matter, forming a belt round the base of the hill, and lying about in large whitish and greyish masses. The trap range does not expire at this point; it merely, instead of continuing, as it had done heretofore, in an east and west direction, turns suddenly to the south, and, sweeping round to the west again, forms by so doing another large valley, along the northern side of which you proceed on the route after leaving Bapyle. The river Dasaon is crossed at Sehorah, thirteen miles from Ságar, and then Gumhariah, another village, occurs, the whole way being on the trap, and the road at a little distance from the trap and sandstone hills, until at length you gradually ascend the sandstone hill of Ratgher, twenty-six miles from Ságar. This hill is wedge-shaped, lengthened out east and west, and at the west end the fort is placed on the brink of a high perpendicular cliff, at the base of which cliff flows the Bina towards the north. To cross the Bina you descend the ridge of sandstone before you reach the fort, turn out of the village down to the right, or northwards into the low ground. The ford of the stream is filled with large masses of sandstone, and is to the traveller, particularly at night, very troublesome to pass. After gaining the west bank, fourteen miles over an undulating tract, having a gentle ascent, brings you to Bagrode, where commences a trap range, on the crest of which you proceed to within three miles of Garspur. During this course, you see to your right a very extensive plain, studded over with trap, and sandstone hills of various forms and aspects, and among these the remarkable sandstone hill of Teonda, with its summit presenting the appearance of a hill fort wall, with its buildings within. The route by Teonda from Ratgher to Bhilsa is often taken for wheel carriages, to avoid the Pass of Garspur. This Pass, the summit of which is about three miles from Garspur, occurs in consequence of the road descending the southern side of the chain, the crest of which it had hitherto occupied in an east and west direction. The chain, too, here becomes forked, one limb stretching south-west in a straight line, though not with perfect continuity of existence, to near Raisen; the other proceeding directly

west to the Betwa. In the angle thus formed the road descends diagonally, and is extremely rough. It is covered, from the highest part to the lowest, with large globular and angular masses of compact and amygdaloidal indurated wacken, of a black colour, whilst the enveloping clays, in some parts of the line of descent, appear yellow, in others a dirty reddish brown ; and there likewise occur at least two strata of the characteristic hard white limestone, the one rather above the centre, the other near the bottom. At the bottom or base of the hill there are collected innumerable masses of the same black boulder as belongs to the hill, intermixed with pieces of black hornstone, showing veins of white quartz ; also knobs of indurated clay, or semiformed jasper of a yellow colour, or yellow and green, two colours ; botryoidal mammillated lumps of a yellow horn-like chalcedony, decaying, and variegated by the green earth contained ; geodes of a pseudo-amethystine quartz, often filled completely with confused crystallisations of the same, intermixed with balls of either a yellow, or pure and transparent calcspar ; thin tables of quartz ; small flattened pieces of common chalcedony ;—thin tables of quartz, white and opaque, alternating in layers with chalcedony, greenish grey and translucent, and coated externally, on the flattened sides, with crystals of quartz, small and brilliant, and other similar siliceous and calcareous matter (the latter not separate and alone), such as once probably was more intimately connected with the amygdaloids, and which now for ages have in the main resisted the force of time and exposure. The moment you are clear of the fallen matter at the foot of the Pass, you step on the sandstone, which is exposed to day in the whole axillary part, the bounding trap ranges resting upon it. It is uneven, much covered with fragments; swells and hillocks appear upon it, and amongst these that on which is placed the village of Garspur, higher than the rest somewhat, but not so high as the contiguous trap. It is situated about a mile and a half from the foot of the Pass, and it possesses some little length, or at its foot the road runs about half a mile in a WSW. direction. After leaving the red ground and coming on the black soil again, the sandstone still continues to attract occasional attention, protruding up through the trap, until you have passed the distance of four miles. From this point for twenty miles there is a general inclination of the trap land to the Betwa, the hills being further and further removed from the view, as you advance in the large open cultivated plain, at the WSW. extremity of which stands Bhilsa on the east bank of the Betwa. Here the sandstone occurs as a large plat of some hundred yards diameter, generally even with the trap; but in the central part it suddenly rises up, and forms a curious clump about 120 feet high and flat at the top, where there is just sufficient area for a Moslem tomb, and another small building or

two, remarkable in the distance from their white appearance. If Bhilsa be taken as a point, and a radius of six miles swept about the west bank of the Betwa, it would everywhere pass over sandstone hills,—they are much clustered thereabouts. Khano Kerah, where is seen a very anciently sculptured rock, is situated amongst them. The town of Bhilsa is placed on the east bank of the Betwa, between it and the solitary sandstone rise alluded to. In a NW. direction a bed of iron clay slopes off this rise, so that the Betwa and the Bheis, which joins the Betwa a little northward, cut through it, and the angle formed by the junction of the rivers is occupied by it; but, after having gained the west bank of the Bheis, it is soon lost. The road now continues on the trap, the hills for six miles being solely of sandstone; more west than this it is merely a trap plain, on which occurs Kamkera, twelve miles from Bhilsa. Beyond Kamkera, the route being now to the northward of west, the plain still continues for five miles, and then you ascend and cross a range of globular trap hills, distant from Barsia ten miles, with nothing remarkable in the interval. Barsia is on a large mound of amygdaloidal iron clay, sterile and bare in some parts, apparently highly productive in others; in the immediate vicinity of the town it is gravelly and red in aspect. Four miles in advance, or at Ranagheri, this clay again presents itself, rises even to the rank of an ore, and is as such worked, and the produce sold sufficient for the purposes of the bazar of Barsia. Immediately around Danaora the sandstone hills shoot up. Kalukera, sixteen miles from Barsia, is on the trap; the Seemera, a small stream, winds about the village, washing out its way through large blocks of wacken and basalt. The fort is built of egg-shaped masses of the latter, truncated at one end, which end is set outwards, something like the flint with chalk to be seen in some of the ancient houses of Hampshire, such as Chawton-house and Farleigh Wallop, though the stones here used are four times as large as a common flint. Between Kalukera and Narsinhgerh (a march of fourteen miles) you pass the Parwa and Parbati, only worthy of notice as showing in their beds the trap and basalt covered with a whitish coating, and cracked into various prismatic shapes. The sandstone range at Narsinhgerh runs directly N. and S. beyond the reach of sight. The village is situated in the deepest part of a circular hollow formed by the partial winding of the hills, and the trap has there found its way, though a basement of sandstone completely occupies the narrow throat, or entrance over which the road leads into the hollow. The trap is composed of balls decomposing, of the concentric lamellar kind, and the water in a well, where this trap was indentified, was 15 feet from the surface in the month of June. Rising out of this hollow you go up a very long and steep ascent of sandstone, and when

the crest of the hill is gained, there is but a trifling comparative descent on the west side to reach the trap. The space between this and Bhopalpur has nothing of interest; the country is more undulating and more open, hills and hillocks are less seen. The Kassa and Duda rivers, occurring before you reach Bheinsa, differ nothing from the Parwa and Parbati, neither does the Newas in advance at Bhopalpur. It is fifteen miles from Narsinhgerh to Bheinsa, and ten more bring you to Bhopalpur on the banks of the Newas, and to an extensive bed of basalt (the Rowley Rag), not rising above the surface; thirty-six miles beyond this point, in the direction of Patan and Kota, *i. e.* at Bhalta, the trap formation ceases. It is seventy-two miles from Ságar to Bhilsa, and eighty-two from Bhilsa to Bhopalpur. In the first part the valleys and low lands are generally pretty well cleared and cultivated, in the latter they are wild and their fertility neglected; they are overgrown with brush-wood and jungle; and cultivation, at least along the line of march, is only seen in small patches about the villages, just sufficient for the support of the inhabitants.

Departing from Bhilsa and taking the route to Hasanabad, the sandstone hill of Raisen is met with at the distance of fifteen miles. It is in shape like that of Ratgerh, but the highest point is the east end, and the fort is perched upon it, facing that quarter. It is very conspicuous for many miles around, and said to have been built by the celebrated King of Ayodhya, as a place of refuge from the temporary anger of his brother, and that the hill arose at his desire, but whether with the aid of an igneous or aqueous power the upheaving was accomplished is, of course, the question here requisite. Banchor, the next stage, as its name imports, is the entrance to a dense forest of timber trees, crowning the summits and sides of a very long winding sandstone range, upon which the road passes through Chiklod, Kuliagerhi, and Akalpur, or a distance of twenty-four miles, and in a westerly direction, and then turns south, or down the slope of the hills twenty miles, through Nezer, Ganj, and Chouka, to the alluvium of the Nermadá. The road descending is extremely rugged, and occasionally slippery, from the size and position of the slabs; it is, in fact, nothing more than a watercourse. It is sixty-eight miles from Bhilsa to Hasanabad. The edge of the alluvium is three miles from the Nermadá. The sandstone peeps to day at Hasanabad, and is seen no more; fifteen miles over the black basaltic mould or alluvium bring you to Petruota, where commence primordial rocks, ending in the granite of Nimpani, Shahpeer, and Beitul.*

* Between Kaishler and the Bhora Nadí there is coal. The Towa Nadí should be followed to its source, or until it is shown from whence it receives the coal fragments found in its bed.

I ought to have stated, that the trap range branching off at Garspur approaches very near to Raisen, and at Banchor forms the eastern boundary of the small valley there; and then, after bending about in a southerly direction, and skirting the sandstone, it proceeds eastwards by the source of the Desaon, Sirmao, &c.—forms, in fact, the southern boundary of the trap formation, as described.

Northwest of Ságar, or in the direction of Seronj, and north, or in the direction of Maltoun, still the country is precisely the same, except, in the latter case, the sandstone hills predominate. Eastward of Ságar the trap is at Sanowda,—so is it at Shahpur, or a march beyond, and ceases only near the nameless rivulet between that place and Pathariah. North-east of Ságar the sandstone often appears, but only as swells rising little above the general level. The trap prevails until you have passed Sanwa, three miles and a half; there it ceases entirely, distant from Ságar forty-five miles. From Sanwa east to Satpara and Panchamnagar in the lias, it is not more than nine or ten miles, and these places are about the same distance from Hirapur, due north of them. A section made from Hirapur to either of these places, and from them to Sanwa, would be highly interesting, and most probably establish clearly the relations of the granite, conglomerate, new red with its overlying trap, and the lower lias.

Where the trap ceases, it does so abruptly. It possesses a vertical thickness of about 60 feet, and it has been cut down to make the slope easy for the road. At the foot of this short Pass, which is still very steep, is the sandstone supporting the trap; and this sandstone is not now a hard, glassy, difficultly frangible, splintery substance; it is become a fine-grained, white, saccharine mineral, with a flat even fracture, coloured externally a light red; and, with the exception of one fall, about half a mile after leaving the trap land, it presents a very even surface, its blocks, being freed of *débris*, forming a pavement base for the road, a distance of four miles; the sides of the road meanwhile showing much overlying loose matter with long grass intermixed, and occasionally trees as you advance, approaching more and more to something of a timber size. Only one small hamlet presents itself, distant from the road-side on the right hand perhaps a mile. At the expiration of this wild flat, three hills are crossed in succession, composed of the sandstone masses, rather sparingly and loosely set together in much red clay and quartzose matter, and covered very densely with jungle and forest wood. These hills are of no great height, but, being separated one from the other by ravines or watercourses, they are short, steep, and troublesome at the points of separation. From the verge of the summit of the last hill, which summit is more than a mile in breadth, you look down, over an intervening conglomerate range, into the valley of Hirapur; and on

descending from the summit within one hundred yards from the base,—speaking as to the line of road or slope, not to the vertical height,—you see the new red sandstone reposing, in a horizontal position, on a stratum of brownish-black ferruginous clay, and earthy iron ore of the same colour. Was not the sandstone to be seen actually reposing on the stratum just mentioned, still that a change had taken place no one could fail to observe ; for the ground, from being bright brick-red, suddenly changes to a brownish-black, with a harsh gritty gravelly tread, as if you were in the neighbourhood of some great foundry; and so it continues to the base of the hill, and onwards along the low ground as far as the conglomerate hills. These conglomerate hills surround the whole valley of Hírapur, and are heaped up immediately on the granite from whence they are derived, or else they rest on hornstone petro-silex. The individual hill at the south-west point, or the point at which the road enters the valley, is not more than two hundred yards removed from the base of the sandstone hill, only separated by a small hollow or curvature, strewed over with lumps of iron ore and pieces of quartz and felspar, &c. but not a fragment of the new red. The component matter of this conglomerate hill, as well as all the rest around the valley, is a sombre, dark red-coloured clay, enveloping variously formed large masses, the conglomerate, or breccia proper, made up of angular pieces of white felspar, and occasionally grey pseudo-limpid quartz, seldom less than an inch in size, agglutinated by a highly indurated cement of the same sombre ferruginous clay just noticed; or the paste is still harder, common quartz discoloured by the oxide of iron. From the conglomerate boundaries to the centre of the valley, the granite everywhere is open to day and laid bare; it rises also in the centre, sinking towards the bounding hills, and iron ore is strewed about all over those hills, and at their feet, even on the granite. The form of the Hírapur valley is oval ; its longest diameter is from west to east, and it is in that direction about a mile ; from south to north it is not more than a quarter of that distance. About the centre, or perhaps a little to the westward of it, is a large pond, on the north bank of which is the village, and near it, or on the east side, a small square Gerhí or fortlet. On two mounds of granite near the Gerhí, also on a swell of the same on the south edge of the pond, nowhere else, masses of gneiss, some half dozen in number, are sticking up, which, from their slab form and slight inclination, oddly and much resemble old tombstones in a churchyard. Both the gneiss and the granite, if they have any inclination, dip to the SW., but of the conglomerate, it being a heap of clay and large stones, nothing very satisfactory can be said ; here and there, amongst the rounded and angular masses, one or two larger than the rest would seem to stand up, conforming in position to the gneiss, with their broader sides something

sloping to the same quarter as the granite and the gneiss, viz. to the SW. This sketch brings the trap and sandstone to their north-eastern limits.

At Hírapur is seen the granite, capped by heaps of ferruginous conglomerate, which conglomerate is connected with a stratum of iron ore on which the new red sandstone is seen to repose,—all this within the space of a few hundred yards. The new red sandstone, from this point, continues, in the direction of Ságar, bare and exposed, freed from any overlying rock, a distance of six miles, or to where it is met by the trap, when for forty-five miles the two together progressively increase in height, until at Ságar they have attained their greatest elevation, or are at least 1,000 feet higher than the spot where the just noticed connection commenced. If a line be prolonged from Hírapur through Bhilsa to Hasanabad, or that quarter of the compass towards which the primordial rocks at Hírapur would seem to dip, such line will have in it almost all the principal points, where the sandstone protrusions are entitled to the rank of hills, and where they are more elongated individually, and more clustered together; for instance, Dhamúní, and Maltoun, Gherpára, and Sátgerh,—Bapyle, Rátgerh,—Gráspur and Bhilsa. The eastern edge of the sketch, as stated in the commencement of this notice, is where the thin covering of the lower lias lies on the upper portion of the new red rock series, viz. clays, marls, and calcareo-arenaceous sandstones, tender and often variegated, and it is desirable to note in particular that such is the case. At the descent to Tendukaira, or at the SE. corner of the trap, it is a sandstone rock; but the connection of this rock with the subjacent matter along the south boundary is concealed by the basaltic alluvium of the Narmadá interposing. The western limits join the trap of Malwa, and therefore it need only be added that I bring the sandstone as far west as Narsinhgerh. Along the north side, probably, there is sandstone the whole length, it certainly does reach up to Maltoun, and forms the bounding rock thence to Hírapur, and iron ore occurs at many points in that line similar to what it is at that particular spot.

To conclude. The rock about Sehore and Bhopal is, upon good authority, considered as similar to that of Ságar; although there was information given that rock salt was there produced, and, of course, the mind conceived gypsum, &c. as equally existing, or, in a word, that the superior portion of the red marl formation was to be found west of the somewhat diagonal line pointed out; but the accuracy of this last report is at present to be doubted, more particularly as gypsum is only known in the Ságar bazar as a production of Rájpootána, and the salt chiefly used is that of the Sambher lake, annually brought along these latitudes, and sold by the Binjaris as far east as Sergúja. However

be this fact, it is, with the exception now noticed, that I wish to offer the sandstone of the districts described from a general personal acquaintance with the whole, as remarkable for the great extent of range it possesses, for the unique abstracted nature of the thing itself, and mode of occurrence. It is ever the same thing at every point of view, void of clays and marls, or any other interstratification; it is the same identical mineral protruding itself through the trap (where the trap overlies), in large angular masses set together horizontally without cement; a substance of apparent simplicity of composition, fine-grained, hard, vitrified and brittle, where it is localised in the midst of the trap of supposed igneous origin, and a freestone of flat even fracture beyond those localities. Highly micaceous and variegated sandstone slates occur in it in nests, or as continuous strata. The massive rock is itself also often bi-coloured, rarely many-coloured. It might be explained and named as the middle division of its formation, but it is not seen to rest on a conglomerate of its own; on the contrary, it is itself seen, at Hírapur, to rest immediately on a conglomerate incident to the granite rock there occurring.

The limestone of the trap is a hard, white, earthy substance, enveloping a few small particles of a yellow calcareous spar. It occurs constantly as a component part of the hills and swells, not of the lower grounds unless as detritus, in small particles washed down from the hills, when it intermingles with the black mould, and then that soil becomes, from the intermixture, remarkable for its fertility. It deserves attention particularly for the semicalcination, and sometimes more, which it would seem to have undergone, and generally for its defiance of classification, and for the jumble and apparent dislodgment from original position which it now exhibits heaped up in the trap. And if, with these considerations, it be reflected that there is no oolite, no chalk, nothing, in a word, posterior to lias, the hope may be indulged that the chert and calcareous dendritic fragments, occasionally found, will, together with other to be substantiated facts, eventually establish it as a continuous portion of the neighbouring lias, disguised and displaced when the trap was erupted, or by that explosive power and plutonic heat which glazed and hardened the sandstone rock.*

As to the trap, it is here a very extensive deposit, though still but part of a whole. All its rocks are basalt, or matter of near alliance with it, and composed principally of hornblende and felspar in an earthy state. It is altogether an earthy deposit; varieties of greenstone, or basalt, or any rocks of a distinct crystalline texture, are wholly wanting,

* The first noticing of the peculiarities of the limestone is due to Captain Franklin, and the idea of the oolites and chalk is given nearly in his own words, but I am responsible for hazarding publicity.

and by such deficiency so many others of the trappean list are equally, it would seem, not to be found; and the idea obtrudes, whether the circumstance of a simple mineral, like this sandstone described, being the including rock or basin, has not debarred complexity, and preserved to the trap singleness of feature, and texture, and manner of being. The colour of the harder basalt is either greyish-black or jet, and that of the softest kindred clay mottled greenish-grey; and all other varieties, as to induration or complexition, vary between these extremes. In the hills, the indurated masses have mostly their angles rounded, and appear heaped up together with a variable proportion of waeke clay, added to which there will be seen frequently a patch of limestone stratum occurring nearest the base. The base of the hills is invariably broader than the summit, and, if the sides of a hill are smooth and even, balled trap or basalt, often a concentric lamellar variety, will be the principal component matter, decomposing and decomposed into a predominating workable clay, still showing the parallel converging layers. The smaller valleys appear much scooped or concave, and underneath their black looking soil lies wacken or basalt, in form and size about a cubic foot, disfigured, and often arranged in a uniform manner. The globular wacken and basalt partially supersede this arrangement in the low grounds, but neither basalt nor wacken, with step-like uniformity, will ever be found forming a hill. Some one or other of the amygdaloids, particularly the toadstone, succeed the soil and compact trap rock in the valleys, and they are often observed occurring at the foot of the hills; but these latter, it should be remarked, are often merely this globular trap, distinctly thrown up on a sandstone basement or flat. Narsinhgerh remarkably shows the trap everywhere surrounded by sandstone, and the lake of Ságar, on a larger scale, is a distinct basin of sandstone with an inner coating of trap. Altogether it may familiarly be depicted as a dark superficies specked with spots of red; the bird's-eye view also presents the thing as a network scene, the interstices being formed by the numerous hills, and low chains of hills, winding about. No sudden brush of the ocean could have left such remains as are here seen, and unless the occurrence of stilbite* be decisive, there are no facts to plead for the aqueous origin of the trap, except the all-pervading character of its occurrence, and its possessing an axis or general line of bearing; but neither of these, indeed, pleads exclusively for it; whilst, on the other hand, common observation here forcibly inclines the mind to recognize an opposite theory, and imagine the action of a globe of compression, or rather of a common mine. The effort is made, and the entonnoir formed by the more vertical rays sending upwards the stuff,

* It has been said that the occurrence of stilbite is decisive of the aqueous origin, which is the reason why I mention stilbite being found.

and strewing it in heaps all about; whilst those rays that are more inclined will either compress and shake, or split and penetrate, according to the various natures of the materials of which the sides are composed; applied to the trap it will thus be an overlying rock, whether it be, as it is seen here, only on the surface, or whether it occur, as it so often does elsewhere, and here too, perhaps, below the surface, interstratified, entangled, and in what not position in other rocks. The works of after ages, by means of either agent, the ocean, for instance, acting through those ages, might have exercised denudation, and disturbance, until only a portion of a more horizontal ray is occasionally to be seen, indicating an explosion somewhere, either proximate or remote from the spot; a stratum, a dike or a vein, occurs of no obvious connection. If the simile of a mine be at all admissible, it may be carried on, and said that, compared with the solid contents of the globe, the product here seems to have been from a line of fougasses continually working results through a long course of time; the ruin lies about, a small portion of which is a half-calcined limestone,—can it once have been the lias? and the chert of Bapyle, and the small fragments occasionally found of a yellow dendritic limestone, the only aids at present in corroborating the idea? and the clays, the yellow and the deep chocolate, and the marly ochres, are they the more unchanged matter, and the laterite an iron ore disfigured and impoverished? The cellular, or honeycomb lava-like variety of trap occasionally is met amidst the abundance of other kinds; whilst the sandstone rock is, as a remains, shook, and split and vitrified, but not displaced or inclined. The fluid matter seems to have shrunk and sunk, and thus, in a great measure, arises the phenomena of the trap in the low grounds, and the disrobed, naked appearance of the sandstone islets, as if their clothing had slipped down. But the incumbent waters, by their under current, not by violent agitation, would seem to have rounded the masses, and further confused the heaps thrown up, and, after the igneous agency had ceased to act, every trace of the sphere of action would be, by those waters, quickly obliterated. The small hummocks which occur so often, and more particularly at the ends of the hills joined by a low neck to them, are mostly amorphous, and then composed of the harder materials;—but often they are something of a cone or a truncated cone, and their component matter soft. They are here of no importance; having been for ages exposed to day, they have become worn at length into that shape which best resists much further demolition, and so now remain.

It is almost superfluous to add that no fossil remains have been found by me.*

* Abundance of fossils have been found in the neighbourhood of Ságar since this paper was written. They chiefly consist of silicified wood and fresh-water shells, and their existence was

The following is a summary of the foregoing sketch. The latitude of Hírapur is occupied by a primitive range, and so is the skirt of the alluvium south of the Nermadá; in the longitude of Udayapur will be a western limit, and a granite range, crossing the Nermadá at Jebelpur, and, stretching northerly, forms the eastern boundary. This basin elongated E. and W., formed of primitive rocks, has, in its interval or hollow, the sandstone deposit, in some one or other of its forms, exhibited nearly throughout; obscurely as when seen through the trap, or thinly covered with a coating of lias; or openly, as in the hundred and ten mile line from Ságar to Jebelpur. From Udayapur, or the western limits to the central part, Ságar, the trap rocks blacken the surface, and at Ságar they rest on the sandstone, which appears not to have much intermediate between it and the proximate primitive rocks. It is a continuation, and a sort of north-eastern bend of the rock of the Malabar Coast from Baroda as a point, and itself contains more, perhaps, than 54,000 square miles.

first made public by Dr. Spry (Jour. As. Soc. Beng. vol. ii. p. 639.—1833), who found on a portion of the limestone formation, designated by Captain Coulthard (p. 214) as belonging to the trap,—"silicified palm trees"; and afterwards, apparently in a "continuation of the same limestone bed," fossil shells. The limestone Dr. Spry termed "travertine," and he noticed that the shells (*Physa Prinsepii*) were "univalves reversed." While the silicified trees were found among the *débris* of trap on the surface of a bed of limestone projecting from the foot of trap hills beside which the Jubalpúr road runs, the shells were found about half a mile distant, in a stratum of limestone underneath 17 feet of hard and soft basalt, when digging a well; at Ságar.

In the Museum of the Asiatic Society of Bombay are several specimens of these shells, presented by Dr. Spilsbury, and a large collection, including numerous polished fragments of endogenous and exogenous wood by Captain W. T. Nicolls, of the Madras Army, all of which came from the neighbourhood of Ságar, together with many specimens of the limestone, which amply illustrate the varieties of this formation. But although there is, apparently, every species of univalve yet described as belonging to the "Intertrappean Lacustrine Formation" (the name by which I have designated the fresh-water deposit of India containing these shells) among these specimens, I have not yet seen a *Unio Deccanensis* from Ságar.

In describing this limestone formation, p. 227, Captain Coulthard observes, "hope may be indulged" that, eventually, its continuation with the thin bed of limestone which overlies the neighbouring sandstone of Bundelkund may be established; but this "hope" has not yet been realised, although the question has become tenfold more interesting since his paper was written.—Ed.

On the Geology of Malwa. By Captain Dangerfield, Bombay Army. [With a Sketch-Map.]

[Reprinted from Sir John Malcolm's "Memoir of Central India," vol. ii. p. 320, *et. seq.*—1823.]

With regard to the geology of Malwa, I enter with considerable diffidence on the subject, not only from the short period my attention has been directed to it, and the yet fluctuating nature of the science, but from the peculiar disadvantages under which I have laboured in the pursuit, and more particularly at the present period in arranging these scanty materials. I shall, therefore, more frequently describe than name minerals and formations, and leave deductions to those more deeply versed in the subject.

Malwa consists of a rich elevated plain, declining gently towards the north, in which direction, with trifling exceptions, flow all its streams. It appears to constitute the northern termination of a very extensive secondary trap formation, which extends from the extremity of the Deckan, and probably even Mysore, forming all the country above the Ghàts, and part of the plains below, on the western side of the Peninsula, and including the islands of Bombay, Salsette, Elephanta, &c. In this formation are contained the great store of cornelians, agates, &c. of the Rajpeeply Hills; and all those interesting Indian antiquities, the great Cave-temples, both Brahminical and Buddhist. The exclusive occurrence of these last in the direction of this tract might probably originate in the facility of excavating and sculpturing the rocks of sandstone, clay, iron ore, and amygdaloid, and the form of the hills and the vegetable coverings so well adapted to these secluded residences, found in this formation. Many mountain ranges, with their subordinate ramifications, occur within this line; but, excepting those which support the elevated table-lands, few rise above six or seven hundred feet above the level of the plains. Malwa itself, though on all sides bounded by hilly tracts, and on the west and north-west by a grand primitive range, which divides it from the alluvial plains of Guzerat, and which constitutes all the province of Mewar (and probably Marwar), contains none but the small hummocks or conical and table-crowned hills, from 100 to 300 feet high, common to what are considered the newer trap countries. To the south the descent into Nemaur by the Vindhya Range, which is in general elevated about 1,650 feet above the Nerbudda, and towards

whose banks there is a considerable declivity, is very abrupt and steep; and the several Ghâts, or passes, which have been made in it, are for the most part bad. As throwing some light on this formation, and as admitting of more minute inspection, I shall first concisely notice the general character of this range, and the valley through which the Nerbudda has its course.

These mountains, like every other in Malwa, appear to be distinctly stratified, consisting of alternate horizontal beds of basalt or trap, and amygdaloid. Fourteen of these beds may, in general, be reckoned, the uppermost of which are usually from 15 to 30 feet thick, but their depth rapidly increasing as lower in position; the amygdaloid being the broadest, excepting the lowest bed of basalt, which appears about 300 feet high, and constitutes the rock of the lower plain. The two or three upper trap strata are fine-grained and massive, but it gradually assumes the state of globular trap, the balls of which are at first small, but lower down increase, till in the last of these beds they are of an immense size. This rock, being well described in Thomson's Details of the Wernerian System, where it is placed in the transition series, needs no further notice. From the great difference in the resistance made to decomposition by these trap and amygdaloidal beds, their exposed ends acquire a very distinct degree of inclination and character; the amygdaloid forming a great slope, and affording a loose mould covered with vegetation; the trap retaining its original perpendicularity and dark bareness. From this arises a remarkable streaked and sharply-defined appearance, which has probably furnished the Germans with the name.

These circumstances, combined with the table-summits (common to hills of this class), formed often of a thick bed of basalt, presenting an outward bluff perpendicular rampart of considerable height, and the occurrence of one or two similar abrupt stages at the foot and on the ascent of the hill, will probably account for the numerous strong fortresses which are found in the direction of this formation. The upper bluff rock required at its summit nothing but a low parapet carried round its verge, or filling up any partial failures in it; and the other stages, with little labour, presented similar advantages for the erection of second and perhaps lower forts; whilst the deep ravines, or water-courses, gave a ready and safe communication between the whole. Asseer is, amongst several similar along the Deckan, Candeish, and the Concan, an instance of such forts, whose chief advantages arise from these circumstances, and probably, with the singular hill of Dowletabad, owe their present state to these characters having suggested to the natives such a mode of fortification, and having afforded them at the same time, perhaps, a facility of execution in the nature of the rock of which I conjecture this last hill is formed.

The amygdaloid of the Vindhya seems to consist mostly of a porous or decomposing wacké, whose cells are lined with green earth, and which are sometimes empty, but more generally filled with globular, compressed, or mammillated masses of zeolites, calcareous spar, or quartz crystals. These usually do not exceed the size of a large almond. The most abundant are the calcareous and mesotype, united in the centre by converging delicate filaments, like fine cotton. Small crystals of cubic zeolite exist, and siliceous crystals, internally filled often with calcareous spar.

Below the Jaum Ghàt, about a mile from the Nerbudda, between Mundleysir and Mhysir, is a cluster of basaltic columns, rising from a small ridge. Their diameters vary from a foot to a foot and a half, and they project from four to six feet above the surface. Their general form is a prism of four or six sides, and the basalt of which they are composed is of a brilliant black, very hard, and of a moderate size grain. These columns are all either vertical or highly inclined, but appear to dip to no particular point. The rock from which they rise, and which constitutes the bed of the Nerbudda for a considerable distance, is a compact or fine-grained basalt, having sometimes imbedded felspar, but is more commonly much intersected by narrow vertical veins of quartz, or thin seams or wayboards of the same basalt, but containing, apparently, a larger proportion of iron. In this rock, or attached to large quartz fragments, are found very beautiful specimens of zeolites, more especially the foliated and the radiated, or prismatoidal (stilbite). In most parts, however, of the northern portion of Nemaur, the rock seldom rises to the surface in the plains.

The banks of the Nerbudda, for a considerable distance, between Mundleysir and Chiculdah, are from 40 to 70 feet high, and consist, independent of a thin upper layer of rich vegetable mould, of two distinct strata of alluvium. The upper, which is very light-coloured, contains a great quantity of indurated marl, and is strongly impregnated with muriate of soda or common salt; which the natives extract, by lixiviation, and subsequent evaporation by the sun, in shallow compartments near the banks, and sell it to the poorer classes, particularly the Bheels, in the neighbourhood. This stratum is usually from 30 to 40 feet thick.

The one on which it reposes, and from which it is divided by a strongly marked horizontal line and a difference of colour (this last being of a redder hue), contains a very large proportion of carbonate of soda in general, but slightly contaminated by the muriate. This bed rarely exceeds 10 or 15 feet thick, and rests immediately on the basalt, forming the bed of the river. In the dry season, both these salts form a thick efflorescence on the surface of the bank, and this alone is collected

by the natives. That from the lower bed forms an article of export for the use of the washerman, &c. &c. but the soda itself is not extracted, like the common salt, nor is its value, but in the above way, known.

In some places, near the city of Mhysir, there are pointed out, in the upper bed or near the junction of the two, large earthen vessels and bricks, asserted to belong to the ancient city of that name, which, with Oojein and above eighty other large places in Malwa and Bagur, are stated to have been, at a very remote period, overwhelmed by a shower of earth. But at present there is no appearance of volcanic matters, though some of the hills, both in the Vindhya Range and in the neighbouring wild tract of Rajpeeply, are said to have hollows, sometimes filled with water near the summits, which have been thought to resemble extinct craters. These I have never seen, and cannot, therefore, hazard an opinion. Earthquakes appear to be, to the north-west, of frequent occurrence, and, if we may judge from the recent one which nearly overwhelmed the province of Cutch, often very severe. These soils are sandy, and with their saline ingredients appear, however, naturally enough, to be derived from the decomposition of the rocks composing the neighbouring mountains, and which each rainy season, with the violence peculiar to India, would bring down and deposit in great abundance.* But how the two strata have acquired their relative position and marked line of separation, it is here unnecessary to surmise or inquire.

The bed of the Nerbudda, consisting, as already remarked, for a considerable portion of its course, of basaltic rocks, gives rise to numerous shallows and small falls. Of these the three principal are, one at Deyree, where the river is much contracted; a second at Sansadarah, a little below Mhysir; and a third at the Hurrin Pall, or Deer's Leap, below Chiculdah, whence, till its entrance into Guzerat, the stream finds its way contracted to within half its usual breadth, between two hilly ranges, and its course being much impeded, so as to render navigation impracticable, by large masses and elevated ridges of the rock.

Passing higher up the stream from Mundleysir, the northern bank, after about thirty miles, becomes rocky and precipitous, and consists of gently inclined beds, chiefly of greenstone slate, containing interposed mica in small grains. But the island of Mundatta, and part of the opposite bank, appear mostly to consist of hornstone slate, of a reddish or greenish grey, and sometimes porphyritic. Above this, for a considerable distance, is, on each bank, a very wild woody tract, resembling that already noticed below Chiculdah, excepting that the river is in general deep and less obstructed by rocks.

* The occurrence of stilbite in the amygdaloid of Elephanta has been pronounced as decisive of that formation being Neptunian and not volcanic. The same remark would, therefore, apply to Malwa.

This part consists of a succession of low hills and deep ravines and watercourses, is covered with high thick forests, and is scarcely capable of being travelled, in most parts for seven or eight miles from the river, by any but foot passengers. Iron ore abounds, but the country being almost desolate it is only smelted at Khautcote and Chandghur for the supply of the Indore and neighbouring markets. It is of a good quality, but, from the imperfect mode of working, the metal is little valued, excepting for common purposes. The hilly tract below Chiculdah is better populated, chiefly by wild Bheel tribes; and nearer Broach, on the southern bank, are the Rajpeeply hills, inhabited by the Coolie tribe. In these hills are situate the several cornelian mines, of which a concise account has been given by Dr. Copland in the first volume of the Bombay Literary Transactions. From Burwaye to Chiculdah, the whole valley, from the Satpoorah to the Vindhya mountains, is nearly level, well watered, cultivated, and inhabited.

In the upper plains of Malwa little diversity exists; cellular (vesicular) or compact trap rocks, and amygdaloid, being found, according to the comparative elevation of the spot. These rocks alternate throughout; but their beds decrease in thickness, proceeding north from the Vindhya. The low hills and ridges have often an upper bed of trap or wacké, in fragments or small masses, covered with or imbedded in a ferruginous clay; and the surface of these hills is thickly strewn with large fragments and apparently rolled masses of the same rock, coarse, and full of cells. Quartz and calcareous spar are, in general, also intermixed. In the hills of any height, compact or massive basalt, or trap, alternating with amygdaloid, are the principal rocks. Every point of view presents the same uniform and distinctly streaked appearance noticed in the Vindhya Range.

In the plain, the vegetable soil is seldom of much depth, generally from three to ten feet, and rarely, as in the central parts, fifteen feet deep. It is either a red ferruginous or a rich black loam; the former compact, the latter light, with deep cracks or fissures in every direction. There occurs in some parts, particularly near the bottom of the small hills and banks of the rivulets, between this bed and the rock, a thin bed of loose marl or coarse earthy limestone, containing small balls of a fine light-coloured clay.

Near Saugur there occurs an amygdaloidal or porphyritic rock, consisting of a compact basis of wacké, in which is imbedded, in great abundance, small globular or reniform masses, but more usually long curved cylinders or vermiform crystals of zeolite. The bed of the Kali Sind mostly consists of a similar rock, but in it the crystals are usually globular and very small, varying in size from a pin's head to a large pea, and having calcareous spar and quartz intermixed, or

forming a minute centre to the zeolite, radiating outwards. At Cherolee, near Kaehrode, are some large overlying masses of trap porphyry. At Jowra, and near Rutlam, are small beds of a coarse calcareous conglomerate. Beyond Dhar, near Sultanpoor, occurs a large bed of a handsome jasper, of purple, green, or reddish, or liver-brown intermixed; and in the neighbouring hills, towards Mandoo, and along the crest of the Vindhya, a great variety of crystallised siliceous, calcareous and zeolitic, minerals abounds. Large tables of agate, whose surface is often covered with delicate quartz crystals, large balls or geodes of agate or quartz, often amethystine, but seldom of a deep or uniform colour, and stalactitic quartz or siliceous sinter, are abundant. These quartz or agate balls vary in size from five or six inches to a foot in their greatest diameter, and the internal cavity is often partially or entirely filled by pure calcareous or double refracting spar. This last mineral occurs in all the hills in large masses. Some of the zeolites are nearly massive, and are of a delicate pink or flesh-coloured tint; and a foliated variety of a brick-red occurs often in narrow seams. Very large and beautiful specimens of the foliated and radiated varieties are the most abundant, some of which can, at first, scarcely be distinguished from tremolite.

Univalve and bivalve shells, particularly buccinum, ammonites, and a species of mussel, abound in the marls and earthy limestones; the ammonites are mostly found in the bed of the Nerbudda near Onkar Mundatta and the falls, but I have not seen any but detached hand specimens, and never imbedded in any rock.

Along the whole bed of the Chumbul is a broad bed or dike of horizontally stratified tabular basalt; each table of which is either rhomboidal or five or six-sided, and their thickness varying from one or two inches to upwards of a foot.

Their diameter is generally about a foot, and the tables are so closely united at their sides, and their summits so level, as to frequently form a smooth pavement, and towards each bank breaking into small steps. Each table appears to have a nucleus or centre of a more compact, hard nature, and from thence to radiate outwards. This rock extends for a short distance from the bank of the river, and has not been observed to alternate with amygdaloid or any other rock; and is therefore, perhaps, connected either with a lower bed of the globular trap, which the Vindhya mountains seem to show as constituting the lower strata; or more probably, as occurring in the same direct line with the basaltic columns in Nemaur, where there also appears a similar dike, is connected with these last.

In many parts of the southern boundary of Malwa, a short distance from Mhow, the country near the Vindhya breaks down into deep romantic ravines from 100 to 300 feet high, the sides of which are either very

steep or perpendicular, and composed of a large-grained massive basalt approaching to rudely columnar. By these some of the small rivers and mountain streams find their way down to the Nerbudda, giving rise to several beautiful waterfalls from 120 to 180 feet perpendicular height. This rock, like that of Nemaur, is much intersected by vertical veins of quartz, or narrow seams of a more compact heavy basalt, which appear to radiate from centres at some distance apart, and after a little way run parallel till the rays from contiguous centres meet. This basalt contains also small crystals of augite, and grains of yellowish or olive-green olivine.

Independent of the vast stores of iron ore in all the boundary hills of Malwa, there is a narrow bed of cellular clay iron ore, east of the Chumbul, extending obliquely the whole length of the province, and said to extend even to the north-east into Harrowtee. It constitutes a low ridge, of which the higher parts, as at the Cave-temples of Doomnar, seldom exceed 200 feet, and which apparently repose on sandstone. In some parts this rock is tolerably compact, whilst in others it has large cavities, in which the same ore exists in a pisiform or botryoidal state. The ore is poor in metal, and not worked.

The upper or northern part of Malwa is chiefly occupied by sandstone and sandstone slates, on which reposes, in most parts, the low boundary range extending across from Chittore to Harrowtee, which consists principally of hornstone, splintery or conchoidal, and in some places the beds of which are so thin as to assume a slaty appearance. Its usual colour is light-greenish or reddish-grey, with thin stripes of a darker purplish red, and a radiated structure. Through the interstices of these beds, in general about half way up the hill, in many places percolate fine springs of good water; one of these occurs near Rampoora, where some stone reservoirs and a small temple, dedicated to Mahadeva, have been built by the pious Alia Bhye. Besides filling these basins, a small stream is conducted through a pipe into the temple, and made to drip continually on the sacred Lingam. Brahmins are attached to and reside at the temple. This range throughout is precipitous, but of nearly an uniform height, generally about 200 or 250 feet, and of an unbroken determined line at the summit. All the beds seem to be horizontal or nearly so, but the upper half of the hill is usually massive.

The sandstones are generally very fine-grained, and vary in colour from a greenish and bluish-grey to a light hair or yellowish-brown and brick-red. The brown varieties have usually rather a larger grain, and contain sometimes a little mica. The grey kind forms a very valuable building stone, and is quarried for that purpose in many places east of the Chumbul. The pagodas and public edifices at Rampoora are built of the yellowish-brown kind, quarried at Bamorie, near the left bank of the Chumbul; and

at Rampoora a magnificent tomb and Serai are erecting, to the memory of Jeswunt Row Holkar, entirely of the grey variety, which, from its durability and the facility and perfection of sculpture of which it is capable, is admirably adapted to the purpose. The same sandstones appear to run not only along the top of Malwa, but, passing round at a short distance south of Jowra, extend down its western boundary. The sandstone slates are sometimes rather coarse and friable, but usually, as about Rampoora, are dark-coloured, fine-grained, and contain often imbedded in the centre a fat yellow clay.

At Jeerun, and passing hence westward towards Odeypoor, are sandstones and sandstone slates of different textures and colours. The principal rock at this first place is, however, a fine-grained yellowish-brown sandstone slate, in which occurs much mica in brilliant minute plates, and between the slaty fracture numerous vegetable remains or impressions of a species of fern, appearing to be in a carbonized state. Some red and white striped varieties of sandstone slates at a little distance are coarse and friable; and near the base of the small mound on which Jeerun is built occurs a bed, apparently overlying, of rather a coarse variegated brick-red and dull-white sandstone.

After ascending the small ridge at Dulputpoora, which consists of a coarse siliceous gritstone, commences an undulating country, consisting rather of a succession of low hills and ridges closely connected. All this tract, till near Cheetakairee, the boundary town of the Odeypoor territories, consists of variegated sandstones, with the same in a slaty form, and of a very fine grain or nearly compact, in smaller quantity.* These sandstones are of various tints of grey and red, in stripes and spots; but, after passing Cheetakairee, the grey kind, in which there are sometimes smaller spots of a brilliant red, is the most abundant, and contains narrow beds of a coarse limestone, and a red marl of a fine grain.

At Cheetakairee are some furnaces and shops for working an iron ore found in reniform or mammillated masses, and of good quality, a short distance southward, and abundantly in all that quarter and towards Neemuch.

Proceeding west, a compact greenish-yellow limestone occurs, with thin beds of a slaty clay of a dull reddish colour, and approaching in appearance to a fine-grained sandstone ; but till near Chota Sadree, where are protruding masses of hornstone, little rock appears till approaching the Doom Ghàt, or Pass, a little beyond it. This Pass is over a low range, in general not exceeding 100 or 150 feet high, and consisting of a hard compound rock, having the appearance of a porphyry

* This appears to be Werner's second or variegated sandstone formation.

of rather a fine-grained* red basis with numerous imbedded crystals of white quartz. Descending from it westward occurs, for a short distance, fine-grained sandstone slates, succeeded by limestone and quartz rocks, in considerably inclined beds dipping towards the east. In these sandstone slates are no vegetable impressions, or at least not so abundant as to be readily discovered.

On ascending from the hollow, commence narrow beds of a yellowish or buff-coloured and glimmering magnesian limestone, and a breccia or conglomerate, apparently of the same basis, but containing small round masses or pebbles of quartz. Thin beds of the same slaty clay also occur for a little way further. After a short distance, however, till near Peeliah, is a cultivated open plain; but beyond this to Dewlia is a very rugged, wild, undulating country, covered with low jungle. The rock, which everywhere rises to the surface, consists mostly of a fine-grained light or yellowish-brown limestone,† and resembling some yellow marbles, and containing at first narrow beds of magnesian limestone, with occasional thinner ones of a large-grained siliceous sandstone, having combined small quartz pebbles and a fine-grained red marl, occurring abundantly towards the latter part near Satola. Hence to Burra Sadree is a cultivated country. At this place is a low range of a fine-grained siliceous sandstone, but beyond it, till near Cannore, the country is covered with a low jungle and a rich vegetable soil. Here occur beds of a syenitic granite, but after passing Cannore a light-coloured syenite forms the principal rock. It, however, differs much in appearance in various parts of its course, from the greater or less prevalence of the hornblende. The ingredients, indeed, are sometimes almost separated into distinct seams, veins of quartz and brilliant hornblende often occurring almost unmixed. Towards Bheindur commences a fine granite, and at that place occur vast beds of the same, but of a larger grain, having light-coloured felspar and white quartz, but mica of a greenish black in rather large plates, and often so abundant as to give the rock a slaty structure or fracture.

A little to the westward of Bheindur the country gradually rises, and for a considerable distance clay slate of a dark-grey colour, and sometimes nearly earthy texture, is the only rock. This is succeeded by the light syenite, for a short way; but thence to Kairoda is a finely granular rock resembling syenite, but apparently a small-grained granite, and owing its greenish spotted appearance to small disseminated crystals of thallite.

* This basis appears to be a fine siliceous grit.

† Apparently the mountain limestone of Werner, and, with the other rocks, constituting perhaps his first flat limestone and first sandstone formations. Northward of this, gypsum and rock salt are abundant minerals; and there are grounds for believing that coal will also be found.

From Kairoda to Durolee is a level, barren, and in some parts swampy tract, crossed north and south by streams of sand, gravel, fragments of quartz, and other detritus; but thence to the mountain range which encloses the city of Odeypoor to the eastward, is mostly gneiss of the waved or banded variety in nearly vertical or highly inclined beds, dipping towards the north-east, and containing or alternating with granite; narrow veins or seams of brilliant slaty hornblende and quartz also occur in smaller quantity.

With respect to this range itself, it is generally from 400 to 700 feet high, and is composed of either massive or columnar hornstone, in most parts finely porphyritic, in others, as at the Deybur lake, forming a large conglomerate with much interposed golden mica. It appears to rest immediately on gneiss, but reposes against, or has enclosed in it, a central bed of mica slate.

A little to the southward of the Deybaree, or eastern gate, leading into the Odeypoor valley, occurs one of those fine lakes* common to Mewar, and in which the Rajpoot princes take great delight, and in their construction spend large sums, not only from their magnificent scale, and summer palaces being built at them, but from the nature of the materials and perfection of the workmanship, the architects and sculptors of Odeypoor being celebrated throughout the neighbouring provinces, and forming a school which alone is thought to produce artists capable of executing great aquatic works. This lake, though one of the smallest, merits notice, not only as affording an example of the general mode of their formation, but as giving a view of the internal structure of these mountains, by means of a great slide or rent occurring at this place.

The small river Bedus, which has its rise in the hills a short distance from Odeypoor, and a branch of which supplies the lake of that city with water, has its course, and is still allowed a partial vent, through a narrow opening in this eastern boundary range, which leads down by the Deybur lake, and, forming two of its sides, joins the larger range encircling that city to the westward. Some convulsion of nature has torn asunder, or caused to slide, upwards of 100 feet of the lower portion of the southern mountain, forming a precipitous grand chasm from 50 to 100 feet broad, the sides of which expose to view enormous columns of hornstone (which appear to be minutely

* These two ranges meet also north, forming altogether a strong inaccessible barrier round the beautiful valley of Odeypoor, and into which there are but three regular passes by fortified gateways, but one or two difficult footpaths are said also to occur. The breadth of the valley is about ten miles, and its length thirty. The situation of the city itself is pleasing; and its approach from the eastward, rising gradually towards the palace, which is itself a fine object, and having in the back-ground rugged, primitive mountains overtopping each other in the extreme distance, is romantic, and gives an air of grandeur which does not belong to it on a nearer inspection.

porphyritic from interspersed mica), highly inclined and dipping towards the east. Through the centre of the mountain occurs a narrow bed of fine light-coloured mica slate.

From the detached portion of the mountain, across the bed of the river to that opposite has been thrown a magnificent dam, faced with marble and adorned with sculptured figures, small temples, and open buildings of the same materials. This dam is 37 feet high above the level of the lake, which is said to be very deep, and whose waters are clear and sea-green. Its length is 334 yards, and it is 110 yards broad at the top, but increases by numerous steps towards the base. On the lake side it is also strengthened by large projecting square buttresses. The Bedas, thus obstructed in its course through these hills, overflows part of the neighbouring valley for about a mile east and west, by about double that distance north and south. It is allowed, however, a partial vent through the chasms, across which rude walls are thrown to allow the escape of the superfluous water when it has attained a certain level in the lake. The valley of Odeypoor itself consists either of gneiss or a fine-grained granite, at first scarcely to be distinguished from some micaceous sandstones.

In passing from Malwa to Odeypoor further southward across the Duryawud Valley, and the Suloombur Range towards the Deybur Lake, the character of the country and order of rocks differ from those described.

Although the country from Mundissor to Pertaubghur is somewhat wild and broken, and again becomes so after a short distance proceeding westward towards Dewlia, it is only on descending from that place in the direction of Phoonga Tullao that we finally enter the boundary hills, and begin to perceive traces of other rocks than those common to Malwa. Near this last place, and at Dewlia, occur two distinct stages or small descents, with intermediate woody, undulating country; at each of these there is a decisive change of rock, the first part consisting mostly of fragments or overlying masses of the trap rocks just quitted; but at the foot of the last descent, near Phoonga Tullao, all traces of these are lost, and syenite and porphyritic rocks form all the small hills and basis of the valleys in this wild tract. This syenite is generally coarse-grained and porphyritic from large imbedded crystals of felspar. It forms the basis principally of the rivulets and valley, but the small hills consist equally of this and clay porphyry. This last consists of a basis of very fine hard clay slate, varying in colour from yellowish to reddish and greenish grey, and containing imbedded crystals of quartz and some felspar both in grains and thin veins, but the latter being usually porphyritic. The syenite porphyry also contains thin seams of a fine green clay slate without quartz. The clay porphyry occurs also at the top and sides of the

hills in large overlying masses. The beds or slaty structure of these rocks have a direction nearly north-west and south-east, are highly inclined, and dip towards the north-east, whilst the hills themselves run nearly north and south. These rocks continue for several miles, till finally entering the Duryawud valley near Peepliah, constituting a very wild romantic hilly tract, covered with low jungle chiefly of the Bamboo (*Bambusa arundinacea* and *stricta*), *Butea frondosa*, Teak (*Tectona grandis*), Bayr (*Zizyphus jujuba*), and Aul (*Morinda citrifolia*), some beautiful small valleys occur in this space; and the more distant hills are higher, steep, long, and narrow or conical, with craggy summits, and their sides covered for the most part with a stunted vegetation.

At Peepliah occur large protruding beds and masses of a coarse-grained granite with black mica, similar to that noticed at Bheindur. This rock continues across the valley to Duryawud. Thence proceeding westward towards Soledew, syenite, but usually of a fine grain and dark colour, and porphyritic syenite, again occur. This syenite contains iron pyrites, and is of extremely difficult fracture. Large beds, however, of a coarse red granite often rise to the surface at the ridges. At Soledew itself a fine-grained sandstone, of a yellowish or greyish-white, and of a slaty structure, occurs in narrow beds with hornstone. Close to the westward of Soledew commences the ascent of the Maunpoor or Suloombur Range, whose general elevation above the Duryawud Valley is 700 or 800 feet, but in many parts 1,000 or 1,200. This range consists almost entirely of slates, with subordinate beds of greenstone, greenstone slate, and a finely granular crystalline limestone of a light grey colour. These greenstone or limestone beds, however, occur principally during the ascent or first part, but become more scarce towards Maunpoor, clay and chlorite slates being almost the only rocks for five or six miles. These slates are vertical or highly inclined, their direction being nearly north-north-west and south-south-east with a dip to the eastward. The clay slates vary in colour from bluish to greenish, and latterly reddish grey; this last occurring chiefly about two miles from Maunpoor, and containing an abundance of brilliant golden mica in minute plates. In this occurs a large bed also of a coarse breccia or conglomerate, having a basis of porous, rather soft clay. The greenish clay slate contains an abundance of cubic crystals of pyrites, and the chlorite slate of magnetic pyrites. The whole ascent of this range, from its immediate base to Maunpoor, a small hamlet situated on its ordinary summit, is about six miles and a half. The only road is a small footpath, either along the beds of several of the little mountain streams rising here and flowing into the Mhye, which has its sudden turn a little southward, or the narrow ledges winding along the abrupt sides of these mountains. The ascent is a task of considerable difficulty and even danger, from the continual obstructions of large overlying masses of the slates every-

where scattered about in wild disorder, and threatening their fall with the slightest impulse. Thick, but stunted jungle covers this range, but consisting mostly of bamboo and teak.

About half a mile north of Maunpoor occur two singular hills, of 150 and 200 feet high, composed entirely of compact white semi-transparent quartz, in parts slightly tinged with red. They rise abruptly from the slates. From the division of this rock into vertical and horizontal fissures arises a singularly wall-like structure, and an angular wild outline, and castellated appearance, which, with its brilliant white colour, contrasted with the sombre hue of the slates, makes these hills at a distance resemble snowy peaks rising from amidst desolation and disorder. Immense beds of quartz, indeed, abound not only in these and neighbouring hills, but in all the lower plains of Suloombur and towards Odeypoor. In the midst of this range occur some small fertile valleys from 100 to 300 feet below its common summit. Such is the pleasant small one at Beerawul, about two miles west of Maunpoor, a distance which may be reckoned the ordinary breadth of the top of these mountains. For soon after passing this small village the road winds, by watercourses and the intersection of the hills, gradually down to the Suloombur Valley, which may be said to commence at Malpoor, by the hills gradually falling off north and south. This whole descent is covered with thick jungle, and is about eight miles long. The same rocks occur and succeed each other as on the Duryawud side; but mica slate appears as the principal rock for three or four miles after passing Beerawul. The coarse red granite seems to be the principal rock in the Malpoor Valley, but afterwards, till close to Suloombur, gneiss. The bed of the Hurnee river at this place consists of the same red granite, in which occur narrow seams of pure flesh-coloured felspar. The hill, at the base of which Suloombur is built, consists of gneiss with thin quartz veins; but immediately beyond it for some distance, almost the only rock is mica slate, in which occur thinner beds of either hornblende and mica, or hornblende slate; but quartz, in beds and overlying masses, is very abundant. The same red granite appears again half way towards the Deybur Lake or Beerapoor; but approaching that place, gneiss. The noble lake, called Deybur or Jay Sagur, has been formed by taking advantage of similar circumstances to those noticed at Odey Sagur. The Goomety river, which formerly burst through a narrow opening in this range, is arrested by a magnificent marble dam thrown across its bed, to prevent which being endangered, a partial vent has been given to its waters at a low part of its banks. This lake presents a deep clear expanse of water; bounded on two sides by fine mountains from 400 to 700 feet high, and projecting abruptly into it. The other sides consist of lower elevations or ridges. The extreme length of the lake is about eight miles, and its breadth from three to four miles. It has some pretty

small woody islands near its centre, on the largest of which a Hindu devotee has taken up his residence. The dike or dam is of superior magnificence and workmanship to that at Odey Sagur, and a handsome palace and attendant buildings have been erected on the hill at its eastern end. Along it also are several pretty small open marble buildings, and at the centre a temple of the same materials. Steps, the whole length of the dam, lead down to the water. These are ornamented by large figures of elephants* on high projecting pedestals, at short distances asunder. The total height of the dam to the water's edge is 54 feet, and its length three furlongs; its breadth one hundred and ten yards. From the premature death, however, of its builder, Rana Jey Singh, it is in an unfinished state. Every part of it is faced with well-cut white marble, and the small buildings, elephants, and all its decorations are of the same stone, which is abundant in the neighbouring grand range. It appears, however, to be much intersected by thin veins of mica.

The base and lower parts of these mountains are of gneiss with quartz veins; but the upper part rises an almost perpendicular bare wall, of a large conglomerate or compound rock, consisting of immense reniform or compressed globular masses of hornstone or quartz, imbedded in a paste of the same, but having interposed a large quantity of golden mica in brilliant small plates, which causes it readily to separate, or divide from the cement in that direction. Thin beds of mica slate occur near the centre of the mountain, with small seams of felspar, and large imbedded masses of lucullite of a black colour and dull conchoidal fracture. Some of the distant hills, by their rounded outlines and woody coverings, appear to want this overlying rock; whilst others seem to be grandly columnar, as at Odey Sagur, with which range it has already been stated to connect; the whole is a branch of the great mountain chain which runs nearly in a direction north and south past the westward of Odeypoor, till it joins the still more magnificent one of Marwar. It divides Guzerat from Malwa, Rath, and Bagur. This grand mountainous tract, as far as our very limited acquaintance with it yet enables us to judge, consists entirely of primitive rocks, principally slates and primitive limestones. Towards Doongurpoor, southward, are chiefly slates with abundance of potstone and pure steatite; whilst northward, marble and rock crystal are abundant minerals. Every part of the fine palaces and garden residences in the lake at Odeypoor is of marble, and the sculptural decorations are not only highly finished, but display a considerable degree of taste. Images, toys, and a great variety of articles of marble, rock crystal, and steatite, are hence, and from Jeypoor, exported to all the neighbouring parts of India. Copper and lead are said to abound a little to the northward, and the mines to have formerly yielded a considerable revenue. But during the late commotions

* These are about seven feet high, and each of a single block of marble.

the operations were suspended, and have not yet been resumed. It is also asserted that silver ore was found, but that it did not repay the cost of working.

Proceeding northward from the Deybur Lake towards Odeypoor, mica slate is the principal rock. The country as far as Ginglah is open and nearly level.

From Ginglah for some distance occurs only the waved gneiss with quartz veins; but on ascending towards Surmur are beds of clay slate passing into chlorite slate, but principally greenstone slate, or porphyritic trap, in which the mica is in rather large plates and very abundant. At Kote ascends a succession of small hills, which appear to consist mostly of a fine-grained but friable pink sandstone, in considerably inclined beds, with thinner ones of pure brilliant hornblende, and containing a little of the same disseminated throughout it. Near Korabur, and for some distance beyond it, the principal rock is a largely porphyritic pink granite, with beds of greenstone slate. From Korabur towards Seeswee, there is a rapid ascent by a succession of low hills covered with stunted jungle; and after the first two miles, almost the only rock is a waved gneiss containing thin beds of a small-grained granite and quartz veins. Near Seeswee, serpentine beds occur, but not abundantly. At Seeswee itself, the principal rock is a brilliant hornblende and quartz mixed with a slaty structure. From Seeswee till near Odey Sagur is chiefly a desolate, open plain, covered with vegetable mould.

Passing from Malwa to Guzerat to the south-west, by Ally and Chota Odeypoor, is a continuation of this same hilly belt; but in general the descent is more gradual, and the hills of less elevation. The order and variety of rocks are nearly similar to those already enumerated.

The first well-marked descent occurs near Tirrella, and continues gradually, for fourteen miles, to Parah. In the greater part of this distance occur the trap rocks of Malwa, succeeded by coarse sandstones and limestones, with immense quartz beds, siliceous gritstone, and coarse conglomerates. The limestone is, in general, coarse, approaching in parts to earthy, of a deep brick-red intermixed with white, and containing often much silex. Towards Goorah commence clay and chlorite slates, and those singular quartz hills mentioned in the Maunpoor Range, but here, from their less elevation but greater length, assuming at a distance the appearance of an encampment. Quartz, indeed, forms, till after passing Goorah, a very abundant rock. Beyond Goorah, till reaching the neighbourhood of Rajpoor, mica slate, with seams of pure felspar, sometimes perfectly white, is the principal rock. In some places, felspar porphyry overlies in considerable masses. At Rajpoor, and thence to Chota Odeypoor, is rather a small-grained granite, in which the mica is black, the other ingredients white; but it differs from that at Bheindur in having the mica in only minute grains,

and in much smaller quantity. At Odeypoor occurs a largely granular red limestone, having a highly glimmering or splendent fracture, and containing disseminated small crystals of rather dark green serpentine, and a very little mica. Granite again occurs till near Jubboogaum, after which, little rock, excepting in large overlying masses, occurs till near the borders of Guzerat, when a coarse millstone grit is an abundant rock, and is quarried in many places for domestic purposes, and sent to Baroda and the surrounding large towns.

With respect to the eastern and north-east boundary, little knowledge has been yet attained of its geological characters; but the country is generally described as consisting of a broad hilly belt similar to that on the west, and in like manner gradually leading down to the lower plains of Bundelcund by what is termed the second range of the Vindhya. Whether or not trap rocks, either of the Malwa, or of an older formation, continue in this direction, has not yet been ascertained; but there are grounds for believing that the tract does not consist of primitive rocks.

In concluding, therefore, this loose, rapid sketch, I have only again to claim your [Sir J. M.'s] indulgence for any deficiencies or errors which may have arisen from the mode in which the materials were collected under the pressure of more important public duties which admitted not of delay, and afforded little leisure; but more particularly from the unfavourable circumstances both of health and time under which these hints have been embodied. Probably these may not affect the general accuracy of the whole, as I have preferred meagreness to error, and rejected much which required more patient research for its confirmation. I cannot also but remark that, considering the disadvantages under which we all labour in this remote quarter from the want of scientific cabinets, works, and instruments, even had fewer obstacles occurred, my limited acquirements in this still infant science would not have probably enabled me to present you with a more finished and perfect performance. My sole aim has been, in compliance with your request, to throw together, in the absence of more perfect details, a few notes I possessed on the geology of Malwa and its adjoining provinces, as an adjunct to its geography, leaving to more experienced and scientific geologists the after-task of correction and perfection of this imperfect outline.

I have added, also, a slight geological sketch. In detail it may perhaps prove imperfect or erroneous; but if it suffice to render intelligible the above remarks, it will have answered the only end I had in view. It is not offered, therefore, as a perfect geological map; subordinate or more limited mineral beds or masses having been neglected, and only the more important or extensive noticed, and a few points having been traced merely from hand specimens. If it, however, prove generally correct, it will possess all the value I attach to it, in its yet immature state.

On the Geology and Fossils of the Neighbourhood of Nágpur, Central India. By the Rev. Messrs. S. Hislop and R. Hunter. Communicated by J. C. Moore, Esq., F.G.S. [With a Map and Sections].*

[Read June 21st, 1854.]

[*Note.*—A full abstract of this Communication appeared in the Society's Journal, No. 40, p. 470, *et seq.*, in consequence of unavoidable delay in the publication of the Memoir itself.]

PART I.†

Geology of the District.

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Physical Geography of the District.—The country to which the following paper refers is the western part of the recently acquired kingdom of Nágpur,‡ lying, with the southern corner of the Ságar and

* Reprinted from the Quarterly Journal of the Geological Society of London, vol. xi. Part 3, p. 345,—August 1, 1855 ; with a few alterations and additional remarks by the Rev. S. Hislop.—Ed.

† Part II., containing the Palæontological portions of this Communication, with Illustrations, will appear in a subsequent No. of the Journal.—[Ed. Quart. Journ. Geol. Soc.]

‡ With regard to the spelling and pronunciation of Hindu names of places, the authors have furnished the following remarks in one of their late letters to the Assistant Secretary :—

"Orthography in India is a very unsettled branch of learning. Those who first stereotyped in English characters the Hindu names of places were most unsuited for the work, and hence most unscientific is the system of spelling practised by the generality of our countrymen. We

Narbaddá territories, between 78° 15′ and 80° 35′ east long., and 19° 35′ and 22° 40′ north lat. It is of a triangular shape, each side extending about 180 miles. Its northern side is formed by the table-land stretching from the Mahádewa Hills on the north-west to the northern extremity of the Lánji Hills on the north-east: the south-eastern side is constituted partly by the chain last mentioned, and partly by a line drawn from its southern base to the junction of the Wein Gangá and Wardhá, which latter river marks out nearly the whole of the south-western side (see Map). The limits, as thus defined, enclose an area corresponding with that surveyed by Lieutenants Norris and Weston in 1826, and amounting by their calculation to 24,000 square miles.

The city of Nágpur is situated very near the centre of this area. In the northern division, where the hills are both most numerous and most elevated, the direction of the ranges is east and west. In the southern, which contains a greater extent of level country, the course they take is generally north and south.

Chourága*d*, the highest summit of the Mahádewa Hills and the loftiest point in our district, rises to an altitude of 4,200 feet above the sea; the usual height of the range, which, entering the Nágpur territory from Gáwilga*d*, passes by Dewaga*d* towards Shiwani, is not above 2,000 feet, though in the east of the same chain, where it goes under the name of the Lánji Hills, some of the peaks attain an elevation of 2,300 and 2,400 feet. At Nágpur the country has fallen to a level of 1,000 feet. On the west, however, it immediately rises by 200 or 300 feet in a succession of eminences, which run parallel to the Dewaga*d* range, until they reach the basin of the Wardhá, when they suddenly sink in precipitous descents, as at Talegaum Ghàt. Towards the east of the capital, the plain extends almost without interruption to the banks of the Wein Gangá, where the general level is about 900 feet above the sea. Still further east, on crossing the river, we find the country preserving its former flatness, except that occasionally it is diversified by ranges of hills running north and south, of which that encircling the lake of Nawagaum is the most considerable. In the southern division of the territory there

follow the Jonesian system, as it is adopted by such societies as the Royal Asiatic. By that every Hindu letter has an English representative, though that representive has more a Continental than an English sound attached to it. The vowels are *a*, *á*,—*i*, *í*,—*u*, *ú*,—*e*, *ei*,—*o*, *ou*. They are in pairs, short and long; *a* unaccented having the sound of *u* in *but*, *á* accented the sound of *a* in *have*; *u* the sound of itself in *full*, its long being just the same sound more dwelt on; *i* the sound of English ē, made long or short as it has accent or no accent. There is only one consonant that may occasion difficulty, that is a *d* written in italics. When so written or printed it is intended to have a sound somewhat like *r*. Thus we write Weirága*d*, whereas it is commonly written Wyraghur. The *gh* for *g* is just a gross mistake, which destroys the etymology of the language to a person who does not know the original Hindu name. Silewá*d*á, as written by us, is usually represented Sillewarra."

are few hills, if any, that rise above 2,000 feet; while the champaign tracts, which abound on both sides of the Wein Gangá and Wardhá, fall, ere these rivers have effected the junction of their united streams with the Godávari, to 800 feet above the sea level.

It will thus be seen that our district presents a water-shed from north to south. The most important rivers which flow through it are the Kanhán from the Mahádewa Hills, which at Kámpti receives the Pech from the same upland tract, and the Kolár,—the Wardhá, which is joined by the Wanná from the hills west of Nágpur, and by the Pain Gangá from the Nizam's country,—and the Wein Gangá, the largest of all, which on its left bank, is increased by the united streams of the Wágh, the Son, and the Dewa, and by the Chulband, and on the right by the Kanhán and Wardhá, after its confluence with the latter of which it takes the name of the Pranhítá, and ere long discharges its waters into the Godávari.

History of the Geological Observations of the District.—The geological structure of the territory, whose extent and natural features have been thus briefly described, has for some time engaged the attention of scientific men in India. Dr. Voysey and Captain (now Colonel) Jenkins were the first who examined it. From the result of their investigations, as published in the Bengal Asiatic Society's Transactions, Part I. for 1829, it would seem that they were unsuccessful in their search for fossils. The lamented Voysey, indeed, who was the first in India to find shells in a stratum enclosed in trap, thought he had discovered, on the journey hence to Calcutta, which terminated his distinguished career, bivalves in a bed of limestone near Ráyepur within the Nágpur State, though on the east of our district;* but I have since ascertained† that the appearances, which he regarded as organic, are the consequence of the peculiar concretionary structure of the rock. The next observer within our field of investigation was Dr. Malcolmson, who in 1833, worthily following up Voysey's discoveries within the Nizam's dominions in 1819 and 1823, pointed out new localities for the formation in the same part of the country, and traced it into this kingdom to Chikni and Hinganghàt. At the former of these places, which is sixty miles south of the city of Nágpur, he met with *Unio Deccanensis*, *Physa Prinsepii*, *Paludina Deccanensis*, and *Melania quadrilineata* : at the latter, which is sixteen miles nearer the capital, he found an abundance of silicified wood. But though he lived in this neighbourhood for some years, he

* Beng. As. Soc. Journ. vol. xiii. p. 856.

† The first person singular here refers to Mr. Hislop, by whom the memoir is for the most part written, with the exception of the description of the Plants and Insects of the Tertiary deposits, which is from the pen of his fellow-labourer Mr. Hunter. For a previous notice of the "Geology of the Nágpur State," by the Rev. S. Hislop, see Journ. Bombay Asiat. Soc. No. 18, July 1853, p. 58, &c.—Ed. Quart. Journ. Geol. Soc.

does not appear to have been aware of the existence of similar organic remains here; and while, with Voysey and Jenkins, he enlarged on the *mineralogy* of Sitábaldi hill, like them he failed to advert to the two rocks which are its most interesting features,—his own trap-imbedded stratum with Physas and Melanias towards the top, and an unfossiliferous member of the sandstone formation resting on gneiss at the bottom. In 1842 Lieutenant Munro, of H. M.'s 39th Regt., brought to light in the sandstone quarries near Kámpti, nine miles NE. of Nágpur, the impressions of ferns, which were forwarded to Malcolmson as having previously discovered the first vegetable remains in the sandstone of the Hyderabad country, by whom they were figured and described as resembling *Glossopteris Danœoides*, of Royle.* As this species of fern is now understood to be a *Tœniopteris*, it seems likely that the comparison of the Kámpti specimens with it was incorrect, and that they belonged to a *Glossopteris*, whose species, owing to the fragmentary state of the fronds, cannot be determined.

In 1845 I procured a few fossils of the same kind from the Kámpti sandstone, and two years subsequently my esteemed colleague, the Rev. R. Hunter, and myself fell in with them in the contemporaneous strata of Chándá, eighty miles south of Nágpur. None of these specimens, however, were preserved, nor was anything further done by us or by others to understand the palæontology of this part of India, until June 1851, when, walking with my fellow-labourer in the neighbourhood of our residence, two or three Physas, in a deposit enclosed in a trap hill about a mile west of Sitábaldi, and two miles in the same direction from Nágpur, forced themselves on my notice. They were at once referred to the fossils which Voysey and Malcolmson had discovered in a similar situation, and the deposit in which they occur was identified with the fresh-water formation that they had traced in several parts of the Nizam's territory, and at Chikni and Hinganghàt in this state. In a few days after, at the same spot, I found the first bone, and Mr. Hunter the first tooth; and, after a week or two, on Tákli Plain, about 2½ miles NW. of Nágpur, I met with the first Fruit and Entomostracan. About the same time, from observing the traces of ancient vegetation on the soft clayey sandstone, used in the absence of chalk for whitening the writing boards in our Mission schools, I was led to make inquiries about the locality from which it was brought, which ended in the discovery of *Glossopteris* and *Phyllotheca* and some seeds or seed-vessels at Bokhárá, six miles north of Nágpur. Ere long we were joined by our friend Captain Wapshare, Judge Advocate of the Nágpur Subsidiary Force, who added many valuable vegetable remains to our col-

* Bomb. Br. R. As. Soc. Journ. vol. i. p. 249.

lection; and it is to his able and generous efforts that we owe, among other rare acquisitions, the first palm and the first mulberry-like fruits. From the red shale of Korhádi, seven miles north of Nágpur, I procured tracks of Annelids, and more recently, in combination with them, the foot-marks of some Reptile: and towards the end of the year, in company with Lieutenant Sankey of the Madras Engineers, I visited Silewádá, twelve miles north of Nágpur, where the sandstone yielded a profusion of rich and most beautiful specimens of *Glossopteris*, and whence have since been obtained a variety of Exogenous stems, several species of *Phyllotheca*, and an interesting specimen, contributed by Mr. Hunter, of an allied genus, which by Lindley and Hutton is reckoned an *Equisetum*, and by Bunbury probably an *Asterophyllites*.* A Mission tour, undertaken about the same time, conducted my colleague and myself past the fresh-water formation at Paháḍsingha, forty miles WNW. of Nágpur, in which was detected an abundance of fish-scales dispersed through the stone. On our return, Mr. Hunter, among the seeds and fruits of Tákli, discovered the first specimen and the greater part of our fossil *Coleoptera;* while we received an accession to our collection of shells from Dr. J. Miller, then of the 10th Regt. M.N.I., who, while on an excursion with Dr. Fitzgerald, had found the fresh-water formation at Butárá near Machhagoḍá, eighty miles north of Nágpur, and also from Mr. Sankey, who had fallen in with it at Pilkápaháḍ, twenty-five miles to the north-west. The latter-named officer, after discovering in the Kámpti quarries the first *Vertebraria*, a fine species of *Phyllotheca*, a long endogenous leaf, and an abundant kind of seed, all of which he liberally handed over to us, proceeded, along with Dr. Jerdon, the Indian ornithologist, in the direction of Butárá and the Mahádewa Hills,† whence they returned with several new fossils belonging to our Eastern Coal-formation, and excellent specimens of the shells previously collected by Dr. Miller, agreeing in general with those of this neighbourhood. In a portion of the Butárá rock which they kindly gave me, I was struck with the appearance of a diminutive creature, which proved to be a second genus of the *Entomostraca*. Ere the first anniversary of the discovery of our earliest *Physa* had come round, several other localities had been ascertained for both the fresh-water and sandstone fossils, and observations had been made on the remains of quadrupeds and shells imbedded in comparatively recent deposits. Since that, on our annual Mission tours, we have become acquainted with a productive site for sandstone organisms at Mángali, sixty miles south of Nágpur, which has afforded a few unusual vegetable remains, a species of *Estheria*, scales and jaws of Fish, and the entire head of a Saurian; we have

* Quart. Journ. Geol. Soc. vol. vii. p. 189. † Ibid, vol. x. p. 55.

passed through districts abounding in laterite and iron ore, and have increased our knowledge of the geological structure of the country generally.

General Geology of the District.—From the rapid survey which we have taken in the preceding historical introduction of the fossils that have been brought to light within our area, it is obvious that its palæontology, contrary to the common idea of Indian formations, is both varied and important; but, even in a lithological point of view, there are few tracts of equal extent that are worthy of more attention; and of all the portions of that interesting area, there is none for interest that can be compared with the vicinity of Nágpur,—its centre at once political, historical, and geological. We have only to take a few steps from our house and we reach the summit of Sitábaldi hill, the scene of as heroic a conflict as ever our countrymen gained in the East. The spot on which we stand consists of nodular trap.* At the distance of a few yards from our feet, just under the brow of the hill, is a narrow stripe of green or yellow calcareous indurated clay, which, on close inspection, is found to contain a number of decaying casts of fresh-water shells. Under this we perceive a bluish-green friable rock, which hardens first into a tough amygdaloid, and then, a little above the level of the plain, down to which it is scarped by the quarrymen, into a compact greenstone. Cropping out from under the foot of the hill may be seen a bed of soft variegated sandstone, and then, according as we look east or west, the prevailing rock covering the plain beyond is either gneiss or trap.

But let us extend the prospect to the horizon. As we stand with our faces to the north, the first glance that we cast on the distant hills shows that there is a marked difference among them. Behind us, on our left, and in front, we follow a long sweep of flattened summits, with here and there a valley to break the uniformity; but no sooner do we look towards the right than we descry a series of round-topped hills rising up at intervals in massive strength. These flattened summits are the tops of trap-hills, which stretch, in the form we see, from our present position to the coast of the Arabian Sea; and these massive eminences are granitic hills which rise up in the manner that meets our eye, at various distances from each other, from the place where we stand to the Bay of Bengal. The intermediate hills and plains, which in front fill up the foreground, are formed of the dolomite and shale of Korhádi, and the sandstone of the basins of the Kanhán and Kolár.

* Plate VI. fig. 2. *Section through Sitábáldi Hill.*—*a*, Overlying nodular trap; *b*, Fresh-water tertiary; *c*, Underlying trap, vesicular for some feet under the fresh-water deposit, then compact, but nodular at the sides; *d*, Highest member of the Sandstone series, which most probably underlies the amygdaloid throughout; *e*, Gneiss, into which much of the Sandstone has been transformed; *f*, Pegmatite.

From our elevated station we are thus enabled to command a prospect of twenty miles in every direction, and the formations that we can trace within that range make up an exact miniature of the geology of our whole area. Nay, were we to go down the hill and walk around its base, in the descent and circuit, which might all be accomplished in twenty minutes, we should meet with almost every rock that is to be found between Bombay and Katták.

The geology of our area must at one time have been extremely simple. Its principal feature was then sandstone, associated with shale and limestone. But now other two formations are discovered on the arena, and these seem on the surface as if they had been two huge icebergs, which approached each other in frightful collision, crushing the sandstone between them, and allowing the fragments to slide out at either end, and scattering them here and there over their own bulk. Or, to speak in language more precise, the sandstone formation, which once occupied the whole space that we have chosen for description, is now covered up by trap on the west, and broken up by granite on the east, leaving only a small diagonal stripe running through the centre, which, after being interrupted at the north-west and south-east, increases in these directions to a broad expanse, while a few detached portions, formerly continuous with it, appear in the body of the trap and granite. It is the juxtaposition of trap, sandstone, and granite in this neighbourhood which invests the geology of Nágpur with special importance, and which, when investigated by competent observers, may shed a flood of light some future day upon Indian geology in general.

Trap Rocks of the District.—The greater part of the trap within our area lies in the west in the shape of a parallelogram, one of whose corners has been encroached on by a projecting portion of Berár and the Betul district of the Ságar and Narbaddá territories. Its greatest length is 120 miles, and its breadth is from fifty to sixty. Its south-western side, on which the irregularity of figure is found, and by which it joins on to the great sheet of basalt in the Dakhan, is formed by the Wardhá. Its south-eastern side, commencing from Suit on that river, crosses the road from Nágpur to Chándá on the south of Chikni, and, passing by the north of the Mángali fossiliferous quarry, extends to Sákrá and Bhiwákund, after which it coincides very nearly with the political division between the Súbás (provinces) of Nágpur and Chándá, which stretches by Lingá, Jámgaum, and A'lasur hills to the north-west of Bhísi. Here begins its north-east side, which skirts the small patches of sandstone on the west of Umre*d* and Kuhi, and, running close by the city of Nágpur, meets with an eruption of granite, and then touches the sandstone basin of the Kanhán and Kolár, after which it again encounters plutonic rocks on its passage up the right bank of the Kanhán to Dewaga*d*. At this ancient Gond fortress, the upland tract of Multái, which

constitutes the north-west side, joins that last described, and completes the parallelogram.

In addition to this, the main body of trap within our area, and connected with it, there is a smaller development of the same formation in the north. Stretching south and east from Dewaga*d*, it fills up the space between the Kanhán and the Pech, and, sweeping westward round the granite at Chindwá*d*á, and eastward by way of the summit of Kurai Ghàt to Shiwani and Chapárá, it merges, along with the Mathur range of hills, in the basaltic district that extends to the Nàrbaddá at Jabbalpur.

The above is, I believe, all the overlying trap within our area, with the exception of one or two isolated portions south-east from Suit, near Waroda.

Granitic and Schistose Rocks.—The plutonic and metamorphic formation, the extent of which I shall now briefly indicate, lies chiefly in the eastern portion of our area. It is intersected by the Wein Gangá for the greater part of its course. The tract on the left bank of the river I have had little opportunity of exploring ; but, from the cursory examination I have given it, I have reason to believe that there is a large development of granite and its allied rocks, including an extensive outburst of porphyry, which coincides nearly with the upper portion of the course of the Wágh river. This eruption exhibits crystals of quartz, and of white, occasionally red felspar imbedded in a dark paste of the same ingredients. On the right bank of the Wein Gangá, in the district near its junction with the Wardhá, the extent of the formation is not so great. It is observed principally in the channel of the Wein Gangá, though it may also be traced around the bases of the sandstone chains of hills, which it has been the means of upheaving. In both the districts under consideration the general strike of the strata is N. and S., corresponding with the direction of the streams and mountain ranges, and in that last mentioned the dip is for the most part to the west. But it is on the north that the greatest development of granite and crystalline schists occurs. There we may perceive these rocks rising to the surface (though it would be hazardous to conclude that there are not others of a different character in the hollows covered up by the deep soil) from Nágpur north-eastward to the Lánji Hills,—a distance equal to the length of our trappean parallelogram, and with a breadth in proportion. This second parallelogram is applied perpendicularly, but unequally, to that previously described. Near the line of contact, *i. e.* in the district near Nágpur, the gneiss and other metamorphic rocks, like the hills and tributaries of the Wein Gangá which run through it, have uniformly an east and west direction, with veins of the massive rock penetrating them at right angles to the strike.

This is the case with the crystalline formation north of the Kámpti quarries, which has communicated to the sandstone strata there and at

Silewá*d*á a southerly dip. As the granitic eruption, however, is traced up the basin of the Kanhán, it is seen to bend round a little, and to give a westerly inclination to the sandstone at Bábulkhe*d*a, Tondakheiri, and Adássá. From the lastmentioned place it proceeds northwards past Sáner and Kelod, in a narrow stripe on both sides of the Kanhán up to Dewaga*d*. Beyond this we find it rising up around Chindwá*d*á, and running west to Betul. But returning to the neighbourhood of Nágpur, we discover, parallel to the great body of the granitic formation on the north of Kámpti, a range of quartz hills running in the line of the strata westward from Wáregaum to Gumtárá. The plutonic force, which has tilted up these, has greatly disturbed the limestone rocks at Korhádi, and given to the sandstone at Bokhárá, on the south of the Kolár, the same dip as we observe at Silewá*d*á and Kámpti on the north of that river.

Sandstone.—But let us now refer to the sandstone formation, which, I have said, exists in the central parts of our area, though only the wreck of what it once was. Its upper member, reduced in thickness by metamorphic agency, may be observed horizontally entering the trap-hill of Sitábaldi on the east side, and again emerging on the west. It is then wholly displaced by gneiss and granite towards the Nág river, after which it again becomes the surface rock for a short distance to the west, until it is a second time overlaid by trap. It remains thus concealed for sixteen miles, when it is seen on the north-west of Yahár at Nimji, whence it extends to Sátnawari on the south-west and Kotwálba*d*i on the north-west. At these villages it is a third time covered up by trap, nor does it in that direction rise again to the surface within our area, or, indeed, I believe, anywhere beyond it. The division of this formation, which proceeds to the north of Nágpur, occupies a part of the basins of the Kanhán and Kolár from Kampti on the south-east to Kelod on the north-west, being about thirty miles long and twelve broad. Its north-eastern border touches the great granitic tract, which stretches from Nágpur to the Lánji Hills, while its south-western boundary is constituted by the trap, surrounded by which three of its detached portions are found at Kutkheiri, Chorkheiri and Chicholi near the source of the Kolár. Were we to follow the direction of these outliers, they would lead us to the sandstone hills beyond our area, that skirt the southern side of the trap chain of Gáwilga*d*, north of Elichpur. But if we suppose the sandstone continued north-west in the line of the Kanhán's course, we arrive, after crossing some miles of trap and granite, at the beds of carbonaceous and clayey shales, which, running under the trap-range of Mathur, appear on the north side, and form the base of the lofty development of sandstone at the Mahádewas. The largest body of this formation, however, lies to the S. in the basin of the Wardhá and Pranhítá, extending, from the termination of the basaltic effusion at Jámgaum hill and Suit south-east

towards Badráchellam in the Godávari, with only a few outliers of trap, as before mentioned, near Warodá, some slight intrusions of plutonic rocks at Segaum, and the west of Chándá, and a prolongation of the granitic series of the Wein Gangá basin which runs south by Dábá as far as Dewalmari, and reappears from under sandstone at the mouth of the Indrawati in connection with an extensive outcrop of schistose strata terminating at Tekalágudam.

A very marked feature in the geology of the country between the Iri and the Wein Gangá is the occurrence of ranges of sandstone hills, running for the most part north and south, corresponding in general direction with ranges of the same formation in the district of Kotá, described by Dr. Bell.* These hills, where they have fallen under my observation, rise from plains of plutonic rocks, by which the strata have been indurated and elevated, though still retaining the horizontal position. Such is the flat-topped chain which stretches on the east of Segaum, and that which terminates in the castle-like bluff of Perzága*d*. On either side of the Wein Gangá we meet with some isolated remnants of the sandstone formation. One of these, but very limited in its dimensions, lies on the banks of the Selári, a small stream which joins the Wein Gangá near the town of Pawani. Another, further down the river, extends for some distance, first on the right bank and then on the left. In the district on the east of the Wein Gangá, a little sandstone proper is met with, in patches among the hills on the west bank of the Gárwi and Wágh rivers, reaching from Mahágaum as far north as Ambgaum.

Laterite, &c.—In various parts of our area we meet with beds of laterite, covering the rocks already described. I have not found it on the west of Nagpur; but it is seen abundantly within the trap-district at Ságar N. of Dudhgaum, and at Pándaratalááw SW. of Umre*d*. At Karanlá, E. of the same town, it overlies plutonic rocks, and from Pawani on the Wein Gangá it stretches in a broad belt, sometimes over sandstone and at other times over gneiss and granite, towards Weiraga*d*. South and west of this throughout all the province of Chándá it occurs more or less. I have already mentioned the fact of its resting on dolomite at Ambájiri. At Máhonda on the Kanhán, straight east from Nagpur,—at Dharmapuri and Karbi in the basin of the Súr River, which flows from Rámtek into the Wein Gangá,—and again in the neighbourhood of Chándpur, further up the Wein Gangá, the same formation is presented to view. But it is on the east bank of the river that its most extensive development is witnessed. Crossing the Ráyepur road at several places, it unites on the north of it to form extensive tracts in the district of Lánji, and all around Hattá and Kámtá.

The superficial deposits that are superior to laterite are either red or black. The former is found in general where plutonic rocks, sandstone

* Quart. Journ. Geol. Soc. vol. viii. p. 230.

or laterite prevail, though instances are not rare of the latter being met with in such situations. The "regur," or black soil, occurs almost universally where trap abounds.

Description of the Strata.—Having thus given some account of the extent of the formations within our area, as they appear on the surface, I shall now endeavour to point out in a descending order their thickness, nature, contents, fossil or mineral, as the case may be, and age.

I. *Superficial Formations.*

1. *Black Soil or Regur.*—The regur* is of no great depth in this district, seldom, if ever, exceeding 20 feet. In some places, as at Tákli village, it is seen to overlie a stratum of brown tenacious clay, which, like itself, is much mixed with "kunker." I have not succeeded in finding any organic remains in the regur, except bones of oxen and sheep, of very doubtful antiquity.

2. *Red Soil.*—The red soil in our area is of greater depth than the black, frequently displaying a section of 50 feet. Like it, it seems to rest on a brown calcareous clay, at the bottom of which there is in general a layer of conglomerate. In river-basins it alternates with layers of loose sand and gravel, often imbedding existing fluviatile shells of the genera *Melania*, *Corbicula*, and *Unio*. In the district west of Nágpur, the rivers often expose a bed of sand and gravel cemented by a small quantity of lime, and in its consolidated state furnishing blocks of sandstone or conglomerate two or three feet thick. This stratum for the most part is unfossiliferous, but near the Kolár, about ten miles north of

* In a Memoir on the "Geology of the Nagpur State," submitted by me to the Bombay Br. R. Asiatic Society in March 1853, and published in their Journal for July of that year, I made some remarks on the origin of the regur. Dissenting both from Voysey's theory of its arising from the decomposition of trap, and Newbold's view of its deposition in the sea, I suggested, from the analogy of the *Tchermoizem*, the probability of its being a subaërial formation that had taken place in marshy situations, where, of course, vegetation would be abundant. As this suggestion has been misunderstood, I may here take occasion to explain it. I never supposed that there was no clay on the surface, while the regur was being formed. There is clay in the Russian soil, with which it was compared. What I intended to say was, that while there was a basis of both silica and alumina (the *débris* not of trap exclusively, but of any rocks in the neighbourhood capable of yielding them), this basis existed in a locality characterised by the excess of its moisture and the rankness of its vegetation, to which two circumstances, and not to the nature of the original *débris*, was due the colour of this celebrated soil. That these causes are adequate to the effect will, I think, be admitted. Stagnant water, as may be seen in cesspools, always communicates a blackness to its sediment; and the grass and other plants that would flourish in the circumstances which we have supposed, would tend materially to the same result. To account for appearances of stratification in the regur, it may suffice to remark that I take for granted that rains, and all the other influences which rearrange and commingle the soil of the Dakhan at present, were at work in former times. The depth of the cotton soil is somewhat overstated in the text. Ten feet is its greatest thickness even in Berar, where we may look for its most typical features. There also it is underlain by brown tenacious clay, that would retain the moisture on the surface.

Nágpur, there occurs in it an abundance of *Paludina*, *Melania*, and *Corbicula*, which, though belonging to existing species, from the nature of the matrix have been much altered since the period of their deposition. Of some the cavities are simply filled with siliceous and calcareous matter, but in the greater number of instances the shell has been completely absorbed, and employed as a cement in aggregating the particles of the rock. A similar deposit is seen at Nágalwa*d*a near Elichpur, to the west of our area; but there, in addition to the fossils just mentioned, it includes *Limnæus*, *Planorbis*, and *Unio*. On the banks of the Sarpan river, near Tondákheiri, fourteen miles NW. of Nágpur, there is an accumulation of the fresh-water shells previously enumerated, with a considerable intermixture of a species of *Bithinia*, and a few specimens of land shells—*Helix* and *Bulimus*. Mingled with these remains of *Mollusca* there was a quantity of jaws, vertebræ, and other portions of *Mammalia*, which were not much petrified; but, I regret to say, they were accidentally destroyed before they could be examined.* In the bank of the Kanhán at Kámpti, about 45 feet under the general surface, I found the shoulder-bone of some mammifer, much increased in weight from the process of petrifaction. Bones in the same state have been discovered lying above ground, between Nágpur and Kámpti, which must have been washed out of the kunkeraceous red soil.

Judging from the relation of the regur and red soil to the brown clay, I am inclined to regard these two formations as contemporaneous; and, from the evidence of the fossils contained in the latter, I would class both as Post Pliocene.

II. The *Brown Clay*, on which I have said both the red and black superficial deposits rest, averages, together with its underlying *Conglomerate*, a depth of 20 feet. The clay is not known to be fossiliferous, but in Tákli Plain there were found, in the conglomerate, apparently the tusks of a large mammal, which had been completely converted into stone, but they were so much affected by the weather as to fall to pieces on being removed. The formation containing them, I suppose, should be assigned to the Newer Pliocene, and will rank with similar deposits at Jabbalpur and elsewhere.

III. *Laterite*.—This formation seldom exceeds 10 feet in depth anywhere in our area. No fossils have yet been discovered in it here, but diamond mines have been opened in it east of Nágpur. Malcolmson,† and after him Newbold, inferred the identity of the sandstone of Central

* Some fragmentary bones, from the banks of the Sarpan, imbedded in a sandy earth, and associated with numbers of *Melania*, *Paludina*, and *Unio*, form part of the series of organic remains forwarded by Messrs. Hislop and Hunter. The bones, having been kindly examined by Professor Owen, prove to have belonged to Ruminants of two sizes,—such as a Buffalo and a small Antelope.—Ed. Quart. Jour. Geol. Soc.

† Bomb. Br. R. As. Soc. Jour. vol. i. p. 250.

with that of Southern India, from the existence of diamonds at Weirága*d*, a town about eighty miles SE. of the capital. The inference, however, is drawn from erroneous premises, which would have been corrected, had these authors personally visited the spot. At Weirága*d*, there is no sandstone near the diamond mines; the only rock in the vicinity is quartzose and metamorphic. It has been too much taken for granted, in my opinion, that the diamond conglomerate of Southern India is connected with the sandstone, within tracts of which it is sometimes found; and hence the arenaceous strata of the Peninsula have actually come to be designated by the name of diamond sandstone. Now although the diamond conglomerate has been found reposing on sandstone beds, yet there is no instance, that I am aware of, of the diamond having been extracted from any one of them; nor are there any data to prove that the conglomerate derived most of its materials from that source. On the contrary, Heyne* has shown that the pebbles at Kondápetta and Ovalampallia, near Kaddápá, are chiefly of chert and jasper, basalt, quartz, hornblende, and felspar. The first two have evidently been derived from the limestone of the neighbourhood, and the rest from igneous rocks. And these pebbles are not contained in a paste of sand, but, according to Heyne, of clay.† It is true the diamond conglomerate may in one place overlie sandstone; but in another place, as at Kondápetta, it may rest upon limestone, while in a third, as at Bejwá*dá*, near Másulipatam, according to the statement of Captain Newbold, it may be found immediately above gneiss.‡ In short, I am inclined to concur in the verdict long ago pronounced by that experienced Indian observer, Dr. Heyne, when he remarked, "All the diamond mines which I have seen can be considered as nothing else than alluvial soil" (superficial deposit). But if the matrix of the diamond be a surface deposit overlying several rocks, I can perceive no propriety in attaching its name to one of these more than another. The matrix at Weirága*d* is a lateritic grit, and it is worthy of notice that, wherever the precious gem is sought for, whether in India or Brazil, there for the most part oxide of iron is diffused.

Having myself met with no fossil in this formation, I have nothing to offer by way of determining its precise age, but would content myself with remarking that it must be posterior to the overlying trap, on which it is found occasionally, though in our district very rarely, to rest.

IV. V. and VI. *Trap and its enclosed Sedimentary Formation.*—The next rock to laterite, in the order of downward succession, is the overlying trap, with which, however, for the sake of perspicuity, it will be necessary to combine the fresh-water formation previously alluded to, and the underlying trap.

* Tracts on India, p. 97. † Ibid, pp. 96 and 105.

‡ R. As. Soc. Journ. vol. viii. p. 245.

Trap, it was before stated, is the prevailing formation in the west of our area; but when that assertion was made it was understood that this volcanic rock is of two kinds,—one overlying, and the other underlying; and that between these two, and therefore seldom exposed to view, there is for the most part found an aqueous deposit. All three generally occur together. The exceptions are met with in the plains, on the outskirts of the trap formation, where we not unfrequently observe the usually enclosed stratum resting immediately on sandstone without the presence of either the upper or lower basalt. In some of these instances it is probable that the overlying rock has been removed, and cases occur of its remaining where no underlying trap has ever existed. On the other hand, there are examples in similar border localities of a single sheet of trap extending over sandstone without being associated with a second sedimentary formation or volcanic effusion.

Though the three formations are generally connected with each other, yet it is chiefly the upper one, viz. the overlying trap, that meets the eye over the face of the country. Leaving out of consideration the very few examples of denudation which have uncovered the fresh-water deposit in the plains, and the equally rare instances of eruption which have there upheaved it on its edge, it is on the escarpments of the tablelands that we may be said to gain our whole knowledge of this department of Nágpur geology. In commencing our ascent of these steep hills, our attention is attracted by a number of blocks near the foot, which are easily distinguished from the masses of basalt among which they have fallen from above. As we make our way up over the hard, dark, vesicular rock, the blocks increase in number, until we come to a friable greyish or bluish-green zone. We must now move slowly and look narrowly, for a few yards of upward progress may conduct us from the soft amygdaloid, where fragments are thickly strewed, to a nodular basalt, where not a trace of them is to be seen. Occasionally the freshwater formation is so thin that a very little earth or herbage may suffice to hide it from our sight. But generally the water from the brow of the hill in the monsoon collects into little rills just at the place where it leaves the nodular trap, and having now gathered enough of strength to make an impression on intervening barriers, it proceeds to plough up the soft deposit, and the still softer subjacent amygdaloid, leaving an interval between each streamlet, like a talus resting on the harder vesicular rock below (see fig. 3).* The thickness of the overlying trap on Sítábaldi hill and the tabulated summits in its immediate vicinity is from 15 to 20 feet, which agrees very exactly with the thickness assigned to it by Dr. Voysey at Jillan. On the Western Ghàts, however,

* Pl. vi. fig. 3.—*Sectional View of one of the Trap Hills near Nágpur.*—*a*, Surface soil; *b*, Nodular trap (15 to 20 feet thick); *c*, Fresh-water deposit; *d*, Soft amygdaloid; *e*, Hard amygdaloid.

according to Colonel Sykes, a stratum of earthy jasper, which is just our fresh-water deposit, was found near Junar under a thickness of from 300 to 600 feet of basalt.* But it not unfrequently happens that, in leaving the plain and climbing up a trappean hill, we may come upon the fresh-water deposit at three distinct elevations. There is, first, the stratum which underlies the nodular trap generally throughout the plain, and which may be seen sometimes laid bare at the commencement of the ascent; then, after passing over hard and soft amygdaloid, we come to another bed, overlaid by nodular trap; on gaining the top of this we reach a terrace, which conducts us to another ascent, where we find, ere mounting to the summit, a repetition of amygdaloid, sedimentary rock, and globular basalt. An example of this occurs at the hill of Gi*dad*, forty miles S. from Nágpur, the top of which has been appropriated by the disciples of a Musalman saint, named Shek Faríd, to a mendicant establishment, which is supported by the donations of Hindus and Muhámmadans alike, from all parts of the Nágpur territory. See the accompanying section of the hill from east to west (fig. 4),† where *a* is the deposit in the plain, white; *b*, the same stratum of a red colour under the terrace; and *c*, a repetition of it higher up, brownish green. Whether there was a fourth stratum above *c*, the quantity of brushwood and want of time prevented me from observing. That all these strata are one and the same, though they differ in hue, I have no doubt. When we become acquainted with the changeableness of this deposit within a space of a few yards, its different phases on the eastern declivity of Gi*dad* hill occasion no difficulty. Near Kátol, forty miles NW. from Nágpur, a similar appearance is presented. There a thick stratum of red clay lies at the foot of the hill, and we see its tendency to slope upwards and lean against the ascent; but we leave it behind, and come upon the amygdaloid, which emerges from under it. The amygdaloid is overlaid by a bed of red clay, which is surmounted by nodular trap constituting a terrace. Above this, before we reach the summit, we meet with a succession of amygdaloid, red clay, and nodular trap again. In ascending the Ghàt to Gawilga*d* Fort, which, however, is beyond the limits of our map, the same thing may be observed. The slope is so steep that the road is carried in a winding direction up its face, and, although there are no terraces, yet, if I remember right, the traveller comes upon our deposit, which is there of a deep red clay as at Kátol, three or four times successively.

From the remarks now made it will be inferred, that the stratum in question is extremely varied. Not only is it of all colours and all mix-

* Trans. Geol. Soc. 2nd ser. vol. iv. p. 419 [and this volume, p. 100.—Ed.].

† Pl. vi. fig. 4.—*Section of Gidad Hill.*—*a*, Fresh-water deposit, as seen in the plain, of a white colour; *b*, Fresh-water deposit, of red colour, under the terrace; *c*, Fresh-water deposit higher up, brownish green in colour.

tures of tints, but it is of all kinds of substance, and all forms of structure. At one place it is calcareous, at another siliceous, at a third clayey, and at a fourth a compound of all three. Here it is soft, and there indurated; frequently the upper layer, which is next the overlying trap, is hardened, while the lower part remains unchanged. Here it is crystalline, there cherty, and elsewhere scoriaceous. In one spot it is full of fossils, in another and neighbouring locality it is utterly devoid of all traces of ancient life. In one part of a hill we see it six feet thick, but as we follow its line along the face of the escarpment we may witness its reduction to little more than an inch. I know not one constant feature that is characteristic of it. In judging of its identity, a very useful guide to follow is its position between the nodular trap above and the vesicular trap below; but even this, as we have seen, fails us on the outskirts of the formation. Extensive experience, that enables us to combine several criterions that would singly be insufficient, is here, as in so many other cases, the only sure help towards arriving at a correct decision.

The greatest depth of the underlying trap, from its lower part being generally concealed, it is impossible to ascertain. It is obvious that, according to its greater or less development, the plain rises into a gentle swell or increases to the dimensions of a hill. Near Tákli, at the spot where almost all the fruits have been discovered, it is only a few inches thick, and a few yards from that locality it thins out altogether; whereas at Sítábaldi hill, where it is observed to rest on sandstone, it attains a thickness of 100 feet; and in hills where its superposition on the sedimentary rock cannot be seen it must be a great deal thicker.

I have been thus minute on the appearances exhibited by the overlying and underlying trap and the deposit enclosed by them, in order that we may have a clear idea of their relation to each other. The conclusions to be derived from my description I need scarcely indicate. It is quite evident that, before either of the volcanic rocks was poured out in our area, there had been deposited on the sandstone a stratum which must have been at least six feet thick. Over this there was spread a molten mass of lava, which hardened the surface of the stratum, and itself cooled into a flat sheet of globular basalt about 20 feet thick. After a period of repose the internal fires again become active, and discharge another effusion, which insinuates itself between the sandstone and the superior deposit; and, accumulating in some parts more than in others, through force of tension, ruptures the superincumbent mass, tilting up the stratum and scattering the overlying trap, or, raising both stratum and trap above the level of the plain, either leaves it a flat-topped hill, or, with boiling surge, pushes up its summit gradually or by fitful effort. In these convulsions, the more recent trap, where it has not tilted up the deposit altogether, has generally encroached upon it, entangling

some of its fragments, converting the greater portion of it into a crumbling vesicular rock, or producing miniature outliers of amygdaloid from materials susceptible of the change.

[*Fossils.*—As the detailed description of the fossils of this Tertiary formation and of the older Sandstone series will form the subject of Part II. of this Memoir, and be published hereafter, the fossils of the fresh-water deposit are here merely referred to in short.

From the collections made by Messrs. Hislop and Hunter and their friends from this deposit,* the authors mention the following organic remains:—

Small bones, probably reptilian.

Remains of a fresh-water tortoise.

Fish-scales, both Cycloid and Ganoid, in great numbers.

Insects, found at Tákli: Mr. Hunter enumerates about ten species of *Coleoptera*.

Entomostracans; five or six species of *Cypris*.

Mollusca, land and fresh-water, in great numbers. The following genera are enumerated:—

Bulimus.†	Melania.	Limnæus.
Succinea.	Paludina.	Unio.
Physa.	Valvata.	

Plant-remains: Mr. Hunter enumerates,—

Fruits and seeds, about fifty species.

Leaves, exogenous, six forms.

„ endogenous, three or four.

Stems, exogenous, few species; some specimens six feet in girth.

„ endogenous.

Roots, six or seven kinds.

Chara, seed-vessels.

In concluding his notice of the Tertiary insects and plants, Mr. Hunter observes:—

Before quitting this part of the subject, it may be observed, that it would not be difficult to conceive with some degree of accuracy the nature of the locality in which the fruits grew. Going back to the tertiary epoch, we find Tákli part of a lake, extensive enough to be bounded at least on the west and south, and probably on all sides, by the horizon. We assume rather than can demonstrate the existence of islands, which break the uniformity of the sea-like expanse of waters. On the higher land of these are forests, mainly of exogenous trees,

* An extensive series of organic remains and of rock-specimens from the superficial deposits, the tertiary beds, the fossiliferous sandstone and shales, and from the crystalline rocks, has been presented to the Society by the authors of this memoir. The fossils, however, have not yet been fully worked out.—Ed. Quart. Journ. Geol. Soc.

† I am now inclined to doubt the occurrence of Bulimus in our tertiary strata.—S. H.

some approaching six feet in girth. More scattered, but yet sufficiently numerous to attract notice, are palms, exhibiting on their stems, when closely examined, protuberances of aërial roots, similar to those so frequently observed on the Wild Date of India. In the more shady valleys are leguminous and other plants, in great variety and profusion; and there may be seen occasionally climbing, by numerous tendrils, over the bushes a cucurbitaceous plant allied to the *Luffa*, its tender stalk weighed down by a ponderous and probably 10-angled fruit. The *Nipadites* here and there fringes the marshy shores; and wherever the water is shallow there rise above it the reedy peduncles of Aroid plants, terminated at one season of the year by spikes of flowers, and at another either by long succulent purple fruit, resembling mulberries, or by large pericarps, that, without minute examination, might be mistaken for cones.]

Age of the Fresh-water Deposit.—It has already been shown by my esteemed colleague, in his concluding observations on the tertiary plants (see above), that the body of water in which the strata containing the above-enumerated fossils were deposited must have been a lake. I shall now inquire at what period that lake existed. The determination of this question is attended with peculiar difficulties. In a temperate climate like Britain, the discovery of a large number of organisms fitted for a tropical abode at once demonstrates that the rock in which they occur cannot have been deposited subsequently to a remote tertiary period. Here, however, where we have a tropical heat at the present day, the evidence derived from such a source is much more equivocal.

Still I think there are sufficient dissimilarities between our recent and fossil floras to prove the great antiquity of the latter. While there is a general resemblance between the two, inasmuch as *Hedysareæ*, *Cassia*, *Luffa*, and *Nipa* are comprehended in both, there may be remarked, on the other hand, the total extinction of two genera, if not an order of endogenous plants, that once flourished luxuriantly here,—I refer to the Mulberry-like and strobiliform fruits, which, though formerly so abundant, have at present no representative either in India or, so far as I know, throughout the world. We must therefore direct our thoughts to some period comparatively remote, when there was a greater uniformity of temperature over all parts of the earth. Of the more ancient tertiary floras, none corresponds with ours so well as that of the London Clay of Sheppey and Belgium. In both of these localities we find *Nipadites*, and in the former also the *Xylinosprionites* and *Tricarpellites*, of Bowerbank, fruits apparently allied to those found at Nágpur.

Of all the animal remains we have collected, scarcely one seems to be identical with forms now existing on the surface of the globe. The nearest approximation to specific identity is in one of the *Cyprides*, and

in the minute discoid *Valvata;* but whether the identity is complete, I am not competent to say. Supposing, however, that it were proved to be so, this fact would merely show, that of all the living tribes inhabiting the waters, or the margin of our old-world lake, not one has survived in India, except a single species of *Cypris*, for the *Valvata minuta* is not now found here, nor indeed does any species of that genus appear to occur throughout Asia. But with these most diminutive exceptions, if exceptions they are to be called, the statement holds good that between our ancient and our modern fauna the agreement is not closer than generic. In the class of fishes, the resemblance even to that extent is true only of one order,—the Cycloidans; while the other order, the Ganoidans, which have left their horny and bony scales so abundantly in our rocks, have entirely disappeared from our rivers and tanks. Of the class Mollusca, while the genera *Planorbis* and *Ampullaria*, now so common in our pools, are altogether absent from this deposit, *Valvata* and *Physa*, so extensively represented in it, both in species and individuals, have disappeared from the plains of Central and Southern India. Of the six genera *Melania*, *Paludina*, *Limnæus*, *Bulimus*, *Succinea*, and *Unio*, which are common to both ancient and modern India, the differences between the recent and fossil species, especially in the *Paludina* and *Limnæus*, are very great. Of the former, we have nothing at all so large as the *P. Bengalensis* of the East, or even the *P. vivipara* of Britain. In the latter genus, none of our species appear to have belonged to the inflated type, but they are generally more on the model of the *L. glaber*, than that of the *L. stagnalis* of our native country.

Combining then these facts, on the one hand we have the total dissimilarity between every species of our ancient and modern plants,—the disappearance from our flora of several genera, if not of something higher—the difference in prevailing type between some of our fossil and existing genera of molluscs, and the removal of others entirely from our continents to regions most remote,—and lastly, a still more decided transference among the orders of our fishes,—data, which all point to the negative conclusion, that it is no newer tertiary that can be compared with our fresh-water deposit. On the other hand, we find generically, specifically, and individually an equality, to say the least, between our Ganoid and Cycloid fishes, and a resemblance between our flora and that of the London clay,—proofs which, in my opinion, lead us on to the positive inference that among older tertiaries the eocene formation is that with which our fresh-water deposit must be classed. Bronn, I perceive, assigned it to the era of the continental molasse. Whether or not the statements above made will be sufficient to show that this view is incorrect, it is not for me to say; at all events, the fossils which we have contributed will enable others to decide.

Extent of the Fresh-water Formation.—The extent of this tertiary fresh-water formation throughout India is very great. In Captain Sherwill's recently published Geological Map we find it laid down on the west of Rájmahál on the Ganges. Following the same parallel of latitude, we come to Ráe near Narwar, about forty miles south of Gwáliur, whence specimens of *Physa* were obtained by Mr. Fraser, formerly Agent to the Governor General in the Ságar and Narbaddá territories. At Ságar itself organic remains were first discovered by Colonel Sleeman, afterwards described by Dr. Spry, and more recently investigated by Captain W. T. Nicholls, of the 24th Regt. M. N. I. East of Jabbalpur, in the same territories, occur the sites Suleyá, where Dr. Spilsbury procured *Physæ* in 1833, Dhunra in the same vicinity, Náráyanpur near Sohájpur, Mandla, and Phulságar, on the north bank of the Narbaddá, and as far up the river as Mohtura and Domádádar, in the Rámga*d* Rájá's country, at all of which localities the same indefatigable and successful geologist found shells, including an abundance of *Physa*, several specimens of *Unio*, and, if I may judge from the figures, of *Limnæus* and *Valvata*. None of them, however, are named.* North of the Narbaddá, near Mándu, univalve and bivalve shells abound in the marls and earthy limestone, as we learn from Captain Dangerfield, who styles them "Buccinum and a species of Mussel"† (*Physa* and *Unio ?*).‡ Leaving the Narbaddá, and coming to the Tapti, near its source, we find that Voysey, as has been mentioned by Malcolmson, in his memoir on this deposit, discovered shells, which he named "Conus and Voluta" (two forms of *Physa ?*), at Jirpa and Jillan, which lie apparently on the north of the Gawilga*d* range.§ On the S. of the same chain of hills near Elichpur, are Muktagiri and Bairám, whence Dr. Bradley procured the excellent specimens of *Physa* and *Unio*, which I had the pleasure of sending to the Geological Society. Returning to Jirpa, we enter the district of Betúl, about 100 miles NW. of Nágpur, which was explored by Captain Ousley, who found shells at Chichundra and Murkha on the E. of the town, at Bharkáwá*d*á, Bheiáwa*d*á, and Jáwará on the S., and at Badori, Kolgaum, Gaikhan, and Bákur on the SW. Passing over the localities within the State of Nágpur, to which sufficient reference has been made in the previous part of this paper, we arrive at the district north of Hyderabad, where, I am informed by a friend, *Physæ* have been extracted from one of the banks of the Godávari at Nándur, and where also fossils were discovered near Hatnúr and Manúr by Malcolmson, and at Medkondá, Shiwalingapá, and Deglur by Voysey, who

* Bengal As. Soc. Journ. vol. viii. p. 708.

† *Physa* and smaller univalves are common at Jam Ghàt midway between Mhow and Mundlesar.

‡ Malcolm's Central India, vol. ii. p. 329.

§ Trans. Geol. Soc. 2nd ser. vol. v. pp. 570, 571.

as early as 1819, when organic remains were almost unknown in India, met at these localities with shells, including, as he thought, "Turbo, Cyclostoma, Buccinum, Helix, and Turritella," some of which may be identified as *Physa* and *Valvata*. Not far from Deglur, on the S. side of the Manjará, Captain Newbold obtained specimens of *Physa* at Munapilli,* and again from between Kulkonda and Digái, on the banks of the Bhima, he was presented with specimens of *Paludina Deccanensis* by Captain Wyndham. These are all † the fossiliferous localities for our tertiary formation with which I have become acquainted, with the exception of Bombay, and Panga*d*i near Rájámandri, afterwards to be more particularly noticed. But besides these, there are many places where the same deposit occurs destitute of organic remains. For example, my friend Mr. Hunter and myself, on a mission tour, traced it almost without interruption from the vicinity of Nágpur, where the fossils cease, westward to Elichpur, a distance of 100 miles and upwards; and while the material of the rock was sometimes a whitish lime, and at others a green or a red clay, we were uniformly unsuccessful in finding in it any kind of fossils. Similar differences are exhibited in the unfossiliferous stratum around Shiwani. At Garhákotá near Ságar, thence to Tendukhe*d*a on the Narbaddá, wherever Major Franklin met with trap, he "always found it in association with earthy limestone."‡ The experience of Captain Dangerfield regarding its position was somewhat different, he having met with it in certain parts of Malwa, as "a thin bed of loose marl, or coarse earthy limestone," "near the bottom of the small hills and banks of the rivulets."§ The country between the Wardhá and the trap region described by Colonel Sykes has not been examined by any geologist, so that no site can be named in it for our lacustrine formation except Jálná; but I remember noticing it on my first arrival in India, nine years ago, at many localities, though I have now forgotten their names. But when we come to the scene of Colonel Sykes's efficient labours,|| we can trace it almost everywhere under the name either of "ferruginous clay," or "pulverulent limestone." The stratum of "red ochreous rock," varying in thickness from an inch to many feet, and in texture from friable to compact earthy jasper, occurs at Nandur and Jihar near Ahmednagar; at Kothul; in the scarps of the hill fort of Harichandarga*d*, and a mountain near Junir; and at

* Bengal As. Soc. Journ. vol. xiii. p. 987.

† I have since read of the discovery of a gyrogonite in a white aluminous shale, which was cut through for the railway between Madras and Bangalore. Wishing to learn whether this chariferous deposit was of the same age as ours, I wrote to the author of the announcement referred to, but received no reply. If it is contemporaneous, this will carry our tertiary formation 200 miles further south than any locality at present known.

‡ As. Researches, vol. xviii. pl. I. p. 33.

§ Malcolm, vol. ii. p. 328.

|| Geol. Trans. 2nd ser. vol. iv.

Sirur, Wángi, and Barloni, between which two lastmentioned places the bed is believed to be continuous. Finally, it occurs abundantly on the Ghàts, frequently discolouring the rivulets, and giving a ferruginous character to the soil over a considerable area.* Pulverulent limestone is generally found in layers, varying from an inch to three feet in thickness, and covered by a few feet of black earth. Examples of it are met with at Jihur and Islampur near Ahmednagar; at Karkamb and at Salsee, ten miles S. of the fortress of Karmali.† Crystalline limestone, which occurs as an imbedded mineral in amygdaloid,‡ and "great masses of mesotype,"§ which are found in a similar position, seem to me, if I may judge from the analogy of the district of Nágpur, to be instances of our formation somewhat transformed. The ochreous rock or ferruginous clay above mentioned was discovered by Newbold at Sindaghi, in the Southern Marátha country, which lies south of Colonel Sykes's district, and it was described by him as "finely laminated bright red bole," from three to six feet thick.|| And this is most probably the origin of the "red clay," which Newbold on analysis found to be the basis of the amygdaloid in which zeolitic crystals abound.¶

The strata of Bombay have been described in an able and luminous manner by Mr. H. J. Carter, of the Bombay Medical Service.** In thickness they greatly surpass anything we meet with in Central India, reaching to between 40 and 50 feet, and they are peculiar in having a little carbonaceous matter covering some of the vegetable remains. The fossils themselves, however, whether animal or vegetable, bear a remarkable resemblance to those which have been brought to light at Nágpur. Thus we find among them a fresh-water tortoise,—the elytra of insects,—an abundance of *Cyprides*, one species of which appears to correspond with the *C. cylindrica* (Sow.), first found by Malcolmson,—a few indistinct impressions of shells like *Melania*,—fruits and seeds, though not of the same genera as ours,—ensiform endogenous leaves, like the Nágpur specimens,—cormiform roots, which differ from ours only in being larger,—and an abundance of dicotyledonous wood.

At Panga*d*i or Peda Panga*d*i near Rájámandri, not far from the mouth of the Godávari, there are found some outlying trap hills, which General Cullen pointed out to Dr. Benza as fosiliferous. That gentleman visited the place, and described one of the eminences as consisting at its base of sandstone, which is overlaid by amygdaloid veined with jasper, then a limestone deposit with fossils, and finally a sheet of basalt. The fossils were stated by Dr. Benza to be partly marine, and partly

* Geol. Trans. 2nd ser. vol. iv. p. 419. † Ibid, p. 420. ‡ Ibid, p. 421.
§ Ibid, p. 425. || Royal As. Soc. Journ. vol. ix. p. 33. ¶ Ibid, p. 35.
** Bom. Br. R. As. Soc. Journ. vol. iv.

fresh-water; but, as his statement was made at a time when not much attention was paid to the distinction between these two classes of shells, it was supposed that it might be incorrect. I confess that I myself was guilty of this wrong to the memory of an able geologist. However, I took steps to discover the truth, and through my friend Lieutenant Stoddart, employed in connection with the Godávari public works, I have ascertained, I am happy to say, that Dr. Benza is substantially right. His oysters were real oysters, though his "Ampullariæ" most probably belonged to some species of *Physa*. "On only one of these hills," says my intelligent informant, "could I find any oysters; but there, I must say, they were as plentiful as stones." At the foot of a hill opposite to this, Mr. Stoddart found several kinds of shells, and among them a *Physa* identical with a species common around Nágpur, which was in the same block with a *Chemnitzia*. There seems to be a great variety of molluscous remains at this locality, and it would well deserve a longer investigation than my kind friend was able to give it.*

Here then we have the best proof which similarity of position and specific identity of contained fossils can afford, that the deposit enclosed in trap at Panga*d*i is properly contemporaneous with our fresh-water deposit in Central India, although a majority of its organisms are truly marine. It is evident that it was here our great collection of fresh water, stretching either in one continuous sheet, or interruptedly, a distance of 1,050 miles, in a direct line from Rajmahal to Bombay, and of 660 miles from N. to the neighbourhood of Panga*d*i, discharged itself by an estuary into the sea. Whether this great expanse of fresh water was one or many lakes, cannot now be determined, in consequence of the disappearance of trap from many situations where once it must have existed; but I am persuaded that the more careful the exploration made in the great basaltic region of Western India, the more evident it will become that the intervals between the lakes, if any there were, must have been exceedingly small. This was the conviction left on my mind by travelling from Nágpur to Elichpur, and this I think will be the feeling produced in the mind of any one, by taking a glance on a map at any district, like Colonel Sykes's, that has been surveyed, even without a reference to a lacustrine deposit.

Minerals in the Trap.—I ought now to describe the minerals contained in our overlying and underlying trap; but this has been so well done

* A small series of fossils from Panga*d*i sent by the authors comprises *Ostrea, Cardium, Venus, Chemnitzia, and Nerinæa?*—Ed. Quart. Journ. Geol. Soc.

More recently I have been favoured with a sight of the fossils from Káteru, two miles N. of Rájámandri, presented by W. Elliot, Esq., to the Bengal Asiatic and Madras Central Museums. They include two species of *Cardita*, four of *Cerithium*, and a *Monoceros* or *Pseudoliva*; but none of them appear to agree with a species at present found in our Indian Seas.—S. H.

by Voysey, in his remarks on the structure of Sítábaldi hill,* that it is unnecessary. One of the most common in the locality just named, though elsewhere rare, is a pitchy black substance, with a sloe-like bloom upon it, lining the amygdaloidal cavities. This Voysey appears to have called "Conchoidal augite": my friend Mr. Carter supposes it obsidian. It occurs in bands lying one above another, which may be followed to a great distance in a horizontal direction. The intermediate spaces seem as if they had been successive effluxes of volcanic matter running along beneath the fresh-water deposit, and then under one another, each efflux being united or welded to the preceding one by a vesicular belt. Many of the minerals that are met with in the amygdaloid are derived from the tertiary strata. This is particularly the case with jasper, the veins of which, as may be learned from Benza's description of Padpangali hill, and, as we perceive in numerous places in this vicinity, are situated just at the zone of the vesicular trap's intrusion on the superior deposit. Sometimes, instead of being jaspidified, the entangled parts of the strata are converted into chert, at other times they are crystallised into ponderous masses of mesotype. In one locality the calcareous matter is diffused as strings all through the amygdaloid, forming seams of kunker, like those represented by Newbold;† in another they are scarcely enclosed within its substance, but remain in blocks at the lower part of the deposit, which are compact externally, but in the interior, where the heat has continued longest, are found to be an aggregation of crystals.

On the plain south of Gi*d*a*d* hill there is lying about a great abundance of spherical nodules, which, on being broken up, exhibit a structure radiating from a central point, so that they have been mistaken for *Alcyonites*.‡ The fakirs, who have located themselves on the top of the eminence, have adroitly taken advantage of this natural phænomenon to exalt the name of the saint whose disciples they profess to be. These nodules, according to them, are so many fruits and spices of different sorts, which Shek Faríd converted into stone, the largest having once been cocoanuts, the middle-sized betelnuts (*Areca*), and the smallest nutmegs. There is a resemblance of the nodules to the last two natural productions; but, as all alike display an acicular crystallisation, it is difficult to trace the similarity of the largest to the fruit of the cocoa. Much light must be introduced into this land before the inhabitants shall be convinced of the falsehood of the alleged miracle, and shall be able to understand that the seeming organisms are simple zeolitic concretions that have issued from the soft subjacent rock. Nodules of the same shape are found in the same formation at Sonegaum, near Kalmeshwar, fifteen miles NW.

* As. Res. vol. xviii. p. 123.

† Royal As. Soc. Journ. vol. ix. p. 33.

‡ Journ. Ben. As. Soc. vol. ix. p. 625.

of Nágpur, but being purely calcareous, their interior consists of a confused mass of rhombic crystals.

The Age of the Trap.—Beginning with the more recent, as we have done in regard to the stratified rocks, we find that the amygdaloid or underlying trap has not only invaded the tertiary formation, but broken it up, and along with it the nodular basalt, by which it is capped. The amygdaloid eruption, then, is incontestably subsequent to the basaltic. But what age is to be assigned to the latter? It is evidently posterior to the fresh-water beds on which it rests. We have thus an overlying effusion of nodular basalt, which has taken place after the tertiary strata, and an underlying intrusion of amygdaloidal trap, which has occurred after the basaltic effusion. Besides these two formations of trap, I know of no others in Central India, either more modern or more ancient. Captain (now Colonel) Grant, in his paper on the Geology of Cutch,* and Mr. Carter, in his memoir on the Geology of Bombay before quoted, have adduced ample proofs to show that in the districts which they have examined, there have been eruptions of volcanic matter subsequent to the amygdaloid; but in all the districts through which my colleague and myself have been called to travel, no trap formation so modern has fallen under our observation. Nor has any more ancient than the overlying trap been discovered. It might be thought, from the occurrence of isolated pieces of trap in the lower part of our fresh-water strata, that while these were being deposited there were sheets of volcanic rock already on the surface of Central India. But it appears to me that there are no such fragments whose existence may not be accounted for on the principle explained by Lyell in his Manual, 4th edition, p. 446, and stated in a preceding page of this paper. Besides at Bhokára and some parts of Tákli plain, where the amygdaloid has not been intercalated under our tertiary formation at all, but where the latter, with its characteristic fossils, rests immediately and conformably on the sandstone, there is not a trace of volcanic matter to be seen. I am inclined, therefore, to doubt the occurrence of any trap in Central India older than our lacustrine deposit. In the southern portion of the Rájmahál hills, M'Clelland† informs us that amygdaloid is found underlying the coal strata of that district. The coal there is manifestly the usual so-called oolitic coal of India, and therefore we have amygdaloid disturbing the jurassic formation. But, if a stranger to the locality may be allowed to express an opinion, I would respectfully submit that the position of the amygdaloid is not conclusive against its comparatively modern origin. It is obvious that the most recent age attributable to an intruded rock, such as it is, cannot be exactly deter-

* Trans. Geol. Soc. 2nd ser. vol. v.

† Report Geol. Survey of India, Season 1848-49. Calcutta, 1850.

mined by observing what strata it has disturbed in one district; for it may have invaded an older formation in one locality, and yet, rising higher, it may have broken in upon a newer formation in another place; or, applying the principle to the case in hand, the very same amygdaloid which M'Clelland calls secondary trap, because it has been erupted among the oolitic strata of Rájmahál, may be tertiary trap here, if it is, as I believe, the identical effusion which has been intercalated between the oolitic and tertiary formations of Nágpur. But for the conclusive determination of this question, the district of Rájmahál with a tertiary formation found in connection with trap in its northern part, and jurassic strata associated with trap in its southern part, presents the most befitting arena.

Mode of its Eruption.—Before leaving the volcanic rocks, it is desirable to indicate the lessons which Central India teaches as to the manner in which they were formed. Now, the first thing which strikes any observer of the great basaltic field of this country is the comparative absence of all cones or craters throughout. I cannot name a spot in all the tract with which I am acquainted, where I could say either the nodular basalt or the amygdaloid came up from below. The nodular basalt seems to have flowed along for immense distances, filling up the tertiary lake, and leaving an arid plain in its rear. Then the amygdaloid, inserting itself between the sandstone and the fresh-water bed, seems to have flowed generally underground on the same scale of grandeur. Sítábaldi hill, which is almost an outlier of the great basaltic region of Western India, being connected with it by a very narrow neck, would be a favourable place for ascertaining whether the underlying trap, which has there accumulated under the tertiary deposit to a considerable thickness, has been forced up vertically through the gneiss and sandstone, which appear around the base of the hill to be inferior to it, or whether it has been horizontally intercalated, as in the generality of places, between the sandstone and the tertiary. I am disposed to take the latter view; but, if the Government quarry were only excavated a few feet lower, as Voysey long ago suggested, it would put an end to all doubt.*

From the statements previously advanced regarding the trappean rocks of Nágpur, taken in connection with the same formation in other parts of the country, it is obvious there is no foundation whatever for the supposition that the great outpouring of basalt in India took place in the ocean. And, although I believe that the fresh water in which it really was effused must have stretched over great areas without much interruption, yet the discovery in the tertiary strata of abundance of

* It has since been ascertained that the sandstone underlies the lower trap about the middle of the hill, and it may be warrantably supposed to do so throughout.—S. H.

pulmoniferous molluscs, such as *Limnæus* and *Physa*,—of plants, such as marsh or shallow-loving Endogens, buried with their roots and fruits almost entire, and therefore not far from the spot where they originally grew,—not to mention the occurrence of an amphibious univalve like *Succinea*, and of land-shells like *Bulimus*, together with great quantities of seeds and fruit and timber, the spoils of the neighbouring dry land—plainly shows that the water in that part of the lake was of no great depth. Indeed it seems obvious that in places, not a few, the water of the lake must have been so shallow as to allow the igneous rock which was poured out over its bottom to rise above its surface into the atmosphere. We must resort then to some other hypothesis than aqueous pressure to explain the horizontalness of our trappean hill-tops, and a cause adequate to the effect is the well-known law by which the surface of liquid bodies is reduced to the same uniform level. To this law volcanic matter is subject in spreading over an area either of land or water. If to this it be objected, that then we should expect the surface of the effusion to appear scoriaceous like modern lavas, it may be replied that naturally all such light materials in the lapse of ages would be worn away.

VII. *The Sandstone Formation.*

Under the amygdaloid, or, where it has not been intercalated, immediately under the tertiary fresh-water strata, is found an extensive series of rocks consisting chiefly of arenaceous beds.

A. The upper member of this series is seen at the foot of Sítábaldi hill, passing into gneiss, into which much of it, as well as most probably all the lower members, have been converted. Without enumerating all its localities, I may mention that a good section of it is presented by a rivulet skirting the Lál Bág, where the layer under the nodular trap has itself been rendered distinctly nodular. It may be observed in the western division of the city of Nágpur; and it stretches in some places under the amygdaloid, in others under the tertiary bed, but for the most part as the surface-rock, through Tákli plain to Bhokárá. At Nágpur and in Tákli plain the strata are of friable sand intermixed with kunkér, and variegated with a deep irony-red and occasionally a purple colour. But it is at Bhokárá where we can understand it best. In one of the quarries there we find it as at Nágpur, only with less of the colouring matter. Going northward to another quarry, we see it on the way overlaid by the lacustrine formation before described, which is capped by a small rise of nodular trap. Arrived at the quarry, which is only about 100 yards from the first, we find the same upper member of the sandstone, now, however, no longer soft and crumbling, but so hard that the hand millstones of the country, which resemble Scottish *querns*, are derived from it; and the ferruginous matter, instead of being

diffused as blotches, is gathered into waving iron bands more indurated still. At this place these upper beds, which are about 25 feet thick, and very coarse, contain angular fragments of a finer sandstone which lies below. Near Bázárgaum the strata where exposed are pierced with irregular holes, which seem to have been caused by the action of rain and the atmosphere. At Kámpti, situated towards their top, and rising even to the surface through the soil, are imbedded huge blocks, some of them angular, but most of them rounded and water-worn, which contain almost all the fossils that have been procured from that interesting locality. At Silewá*d*a, towards their lower part, there occur a considerable number of compressed stems of trees *in situ*, one of which, presenting its thin edge in the side of a quarry, may be traced for about 20 feet. A few inches further down we come to the largest of the iron bands, which consists of a conglomerate, about six inches thick, enclosing fragments of dicotyledonous wood converted into a kind of jet, and impregnated with iron. Ferruginous bands are common not only at Silewá*d*á, but also at Bábulkedá and Tondákheiri. It is only, however, in the neighbourhood of Chándá that any one of them has been found to contain wood in a silicified state.

B. Underlying the iron band we come to layers of a much finer kind, consisting of argillaceous sandstone, varying from white to yellow and pink, and generally containing specks of mica. These strata, which are used for pavement and carved work, extend downwards for about 15 feet, when they gradually become coarser until they are suitable for millstones. The entire depth of these layers, after their change from fine to coarse, has not been ascertained. Dispersed through them, as we saw was the case with the upper member, are occasional angular fragments, so that it is difficult to distinguish lithologically between the two, except that the inferior beds always contain less oxide of iron than the superior.

It is in the argillo-arenaceous strata that we have met with nearly all the fossils which the sandstone of Silewá*d*á, Bhokárá, Babulkhedá, Bharatwádá, Tondákheiri, Bárzárgaum, Chorkheiri, and Chándá has yielded; and there is every reason to believe that the imbedded blocks of Kámpti also, which have furnished so many vegetable remains, were originally derived from them.

Chorkheiri and Chándá are the furthest limits north and south from which I have procured fossils of the inferior member of the sandstone; and the fact, that the fossils are exactly the same, in addition to a resemblance in litholegical characters, demonstrates that the strata are so also.

Between these two extreme points, however, under an outcrop of coarse sandstone of much the same character as the generality of our upper beds, except that it is not coloured by iron or pervaded by iron

beds, there are found at Mángali and its neighbourhood fossiliferous strata applied to the same architectural purposes as our ordinary lower strata, though they differ from them in being of a deep-red colour, finer and more sectile, and with a larger admixture of clay and mica. As the Mángali red slaty sandstone contains scarcely any organic remains common to the inferior layers about Nágpur, it is not without hesitation that I include it under the present head, and arrange its fossils along with those of the more typical strata.

[*Fossils of* B.—For the same reasons as stated above, p. 263, in the case of the palæontology of the tertiary deposits, the numerous fossils of this division of the sandstone series are here merely mentioned in short, their detailed description being deferred until the publication of Part II. of this Memoir.

These fine and coarse argillaceous sandstones, rich with plant remains, have afforded,—

Labyrinthodont Reptile* (from Mángali).

Fishes ; small jaws and ganoid scales.

Crustaceans ; *Estheria*.

Plant remains.

Fruit and seeds ; numerous and undescribed.

Leaves ; Conifer, Zamites, Poacites, and Ferns (*Pecopteris, Glossopteris, Tæniopteris, Cyclopteris, Sphenopteris*).

Stems ; exogenous and endogenous.

Acrogens ; *Aphyllum, Equisetites, Phyllotheca, Vetebraria*.]

C. Between the sandstone quarries at Bhokárá and Korhádi, granitic rocks have lifted to the surface, with a dip of 30° to SW., a series of red shaly beds ; and between these and Bhokárá another species of green argillaceous strata, lying somewhat more horizontal. The relation of these two to the sandstone beds, from the absence of any good exposure, I have not been able to ascertain ; but they would appear to underlie it. Besides the locality now named, these rocks are developed in the district north of Chándá ; but they require to be distinguished from the green shale in the vicinity of the Mahádewas, which is associated with the beds of Indian coal, and rightly classed under the sub-division B. The red shale at Korhádi has yielded the following organic remains :—

Fossils of C.—A reptilian footmark of one-third of an inch long, and as much broad. Three or four specimens have been obtained, each exhibiting only one print ; owing to the brittleness of the matrix, I am not sure that all the impressions are of the same kind.

* The *Brachyops laticeps*, Owen. See Quart. Journ. Geol. Soc. vol. x. p. 474 ; and xi. p. 37, pl. 2. [and this vol. p. 288.—Ed.].

On the same specimens that bear these footmarks are seen the tracks of worm-like animals. That the animals forming these tracks have been Annelids, resembling earth-worms, will be evident to any one who considers the appearanee of the furrows, the way in whieh the head has occasionally been pushed forward and then withdrawn, the tubular holes by whieh the ground has been piereed, and the intestine-shaped evacuations whieh have been left on the surfaee. Fossil worm-borings have been found in the green shale of Tadá*d*i, NW. of Chándá, seventy miles S. of Nágpur.

The only vegetable organism which has been diseovered in the shale is a sulcated plant, which most probably belongs to the genus *Phyllotheca;* but as a suffieient length of the stem has not been obtained to display the articulation, its preeise charaeter eannot be fixed.

D. Immediately below the red shale there are found beds of white marble at Korhádi, which have been greatly disturbed and dolomitised by the plutonic rocks above referred to.* Similar strata, but pink and blue, oecur in the channel of the Pech at Gokala, a little above Parshiwani; and still higher up at Nawagaum it rises into a chain of eminences, which runs thence westward to Kumári. Following up the river still further, on its right bank we come to a pateh of the same crystalline limestone at Dudhgaum, where it is in the vieinity of trap. To the east of this, at A′mbájiri in Chánpur, it oceurs again: but there, as in most of its other localities, the granite rises to the surface in the neighbourhood. Limestone is found also on the Lánji Hills at Kunde and near Bhánpur, to the east of Hattá; but whether it is the limestone assoeiated with sandstone, or just a calcareous phase of our fresh-water tertiary formation, from not having visited the spot, I am unable to decide. It seems to be comparatively free from magnesia, in which it differs from the generality of the strata of which we are now treating. From the heat to which these have everywhere in our area been subjected in the process of dolomitisation, we need not expeet to discover in them any organic remains. Newbold thought that he had found, in certain eherty veins of limestone near Kurnúl, myriads of spherieal Foraminifera. We have also veins of chert in the Korhádi limestone, which exhibit appearances that might be mistaken for the same objects, but they do not seem to be really organic. The minerals most abundant in the dolomite are tremolite and red and yellow steatite, whieh last, when the surfaee of the roek is weathered, stands out in little prominenees, as if it were a species of liehen.

* This dolomite ought to be ranked with the metamorphic rocks. The calcareous strata on the Lánji Hills seem to be the only true representatives in our area of the argillaceous limestone of the Southern India. In the Rágpur district, east of our area, argillaceous limestone abounds.—S. H.

The whole series of strata which we have desinated by A, B, C, D we conceive to be only subdivisions of the same formation. They have been disturbed by the same granitic eruptions, and, where fossiliferous, bear a general resemblance to each other in their organic remains. But this mutual connection is more apparent when we compare the series within our area with strata beyond it. From Mr. Sankey we learn that the sandstone represented in the north-west corner of our map is succeeded, in a descending order at Chotá Barkoi, by bituminous shale with fossils and sandstone, and at Bhuwan, at the foot of the ascent to one of the Mahádewa or Pachma*d*i Hills, by indurated green claystone and green shale, and bituminous shale with fossils. Again, below the sandstone in the south-east corner of the map, as we are informed by Dr. Bell, there occur argillaceous limestone, bituminous shale with fossils, and a few alternating layers of impure limestone and bituminous shale, until we come to a bed, eight feet thick, of laminated sandstone, &c. Situated, as our sandstone is, between these two extreme points, and appearing to be a bond of connection between them, we might, *à priori*, expect that the intermediate beds would be of the same age as those at the localities on either side ; and this opinion is confirmed by the appearance of the sandstone near Nágpur, which shares, with the sandstones of the Mahádewa and Kotá Hills, the distinguishing feature, first noticed in this neighbourhood, of being pervaded by ferruginous septa. These dark-brown stripes, which, in all their hardness, protrude from the weathered surface of the enclosing rock, will be found, wherever they occur, a very good criterion of judging of the age of the sandstone. But besides identity in the arenaceous beds of our whole district, we can trace the same identity between the subjacent strata at Nágpur, Pachma*d*i, and in the Hyderabad country. The green shale at the Mahádewas and that at Tadá*d*i are different.

At Kotá, according to a private letter with which I was favoured by (the late) Dr. Bell, red clay, of greater thickness than any stratum that was passed through, underlies the other shales which he has enumerated in his section :* and in localities further south, Malcolmson states† that the shales on which the sandstone rests are blue, red, green, or pure white. The strata at Mundipár are metamorphic ; and, as we are told by Newbold,‡ the sandstone of the Eastern Ghàts frequently " passes into red and green argillaceous and siliceous slates and laminated marls." I think, then, that though inferring the identity of Nágpur sandstone with that of Southern India, from the occurrence of diamonds at Weiraga*d*, Malcolmson's statement was wrong as to its grounds, yet it was perfectly correct as to its matter. The position of the shale in

* Quart. Journ. Geol. Soc. vol. viii. p. 232.

† Trans. Geol. Soc. 2nd ser. vol. v. p. 543 [and this vol. p. 7.—Ed.].

‡ Journ. As. Soc. vol. viii. p. 167.

reference to the limestone seems to vary. At Korhádi it is the superior rock. Such also is its position at Bángnápilli, according to Malcolmson,* and generally according to Newbold. In a section, however, of the Pass at Mudalaity, given by the latter writer, we have the following order: "compact light-coloured sandstone, 120 feet; limestone, 310 feet; shales, 50 feet; laminar and massive sandstone. Whereas by the section obtained by Dr. Bell† we find sandstone, from 50 to 500 feet; argillaceous limestone, 9 feet; and, after various unimportant argillaceous, bituminous, and calcareous strata, in all 4 feet,—limestone, 1 ft. 9 in.; laminated sandstone and shale, 8 feet; and argillaceous, &c. strata as before, 11 feet 8 inches,—we come to limestone, 23 feet; then argillaceous and calcareous beds, 25 feet; red clay, 27 feet; and limestone." Here it would appear that shale, sandstone, and limestone are interstratified.

Though there is no great development of carbonaceous beds in the district which is the more immediate subject of this paper, yet I should regard the communication as incomplete without some notice of the position of the Indian coal in reference to our sandstone strata. Bhuwan, in the north-west of our area, at the foot of the Mahádewa Hills, furnishes us with a common term of comparison.

Thickness of the Strata.—A. The highest beds, as exposed in the quarries of Silewá*d*á and Bhokárá, average about 25 feet of coarse sandstone, with iron bands; below which there are 15 feet of argillaceous sandstone, B, with an abundance of fossils, and an undetermined depth of coarse sandstone beneath. These constitute what Mr. Carter, in an able Summary of Indian Geology, which I have just received, calls the "Panná" sandstone. From outcrops of this subdivision of the sandstone series in other localities near Nágpur, the whole thickness of the highest beds may be reckoned at about 200 or 300 feet. At Kotá, as we have seen, it ranges from 50 to 500 feet, at Mudalaity 120 feet, and at the Mahádewa Hills, according to Mr. Sankey, 2,700 feet, which must be its greatest development. C. The depth of the shales at Korhádi and Tadá*d*i seems to be green about 30 feet, red 50 feet. At Kotá, omitting interstratified argillaceous limestone and sandstone, all the argillaceous thin strata united amount to 29 feet, red clay 27; while at Newbold's section of Mudalaity, where the shales, usually reddish, underlie the limestone, they attain a thickness of 50 feet. D. The limestone which underlies the shale, has been much disturbed by granite at Korhádi, so that we cannot fix its thickness precisely; but I should think it cannot be less than 100 feet—at Mudalaity it is 360 feet. Under this limestone, which is included in Mr.

* Malcolmson, *ut supra*, p. 541 [and this vol. p. 5.—Ed.].

† See also Quart. Journ. Geol. Soc. vol. x. p. 374, and *note*.

Carter's excellent paper, along with shales and coal, under the name of Kattrá shales, there occurs, as Newbold has shown in Southern India, and Franklin in Bundelkhand, another series of sandstone rocks, for which Mr. Carter proposes the name of "Tará" sandstone; but as, most probably, owing to the intrusion of the granite, this member of the formation does not occur in our neighbourhood, I have nothing to say regarding it.

Character of the Formation.—There can be little doubt that the upper strata are lacustrine. The occurrence in them of such an immense collection of terrestrial vegetation, intermingled with *Poacites*, taken in connection with the total absence of Fucoids and other marine plants, shows very plainly that they must have been deposited in fresh water. And, as no river could have covered the extent of surface which these beds occupy, we are bound to conclude that, like the tertiary rock previously described, they must have been formed in a lake, a conclusion which the discovery of *Estheria* (or *Limnadia*), with their two valves entire, and congregated together as they are found in their usual haunts, fully justifies. Again, the abundance of worm-tracks and borings in the red shale of Korhádi, and the green shale of Tad*á*d*i*, renders it more than probable that the strata at these localities constituted the margin of an ancient lake, and not of a sea or even of a river. Of the origin of the dolomitic beds it is impossible to give any certain account, owing to the transformation which they have undergone, though we may suppose they follow the analogy of the other members of the formation. The character of the upper strata at Elichpur, as would appear from the fossils discovered by Dr. Bradley, is exactly the same as at Nágpur. The *Lepidotus* which has been found at Kotá, from its association with terrestrial vegetable remains, has been pronounced to have been probably an estuary or inshore fish; but as the genus also occurs abundantly in the fresh-water strata of the Wealden, it may be presumed that the strata at Kotá are not of a different origin from those in our neighbourhood. This supposition is rendered more likely by the fact that while no marine vegetation is said to have been detected there, a piece of the shale which Dr. Bell kindly sent me bears the impression of a bivalve exceedingly like a *Cyrena* or *Cyclas*. Dr. M'Clelland seems to suppose that the Burdwan coal-measures were deposited in a sea, for, in the last plate of his Survey already referred to, he has figured a fossil which he has called *Fucoides venosus;* but any person who compares the plant there represented with the *Glossopteris* figured in his plate xv. under the name of *G. reticulata*, will, I believe, agree with me in considering both plants generically, if not specifically, the same. I infer, therefore, that there is no evidence whatever to prove that our sandstone, or the shale at Kotá, or the Bengal coal-measures, were deposited in the

sea; but, on the contrary, every reason to believe that they were all formed in a large body of fresh water.

Age of these Strata.—The coarse iron-banded sandstone above, and the more fissile strata lying conformably below, which are undoubtedly of one and the same era, require first to be considered.* For the sake of clearness, however, I shall refer to the latter member alone, as it has afforded most of the fossils, and furnishes the best data for comparison with the rocks of other localities. Some of the seed-vessels which it has yielded bear no very distant resemblance to those of the Stonesfield slate; *Asterophyllites? lateralis*, to use the provisional name proposed by Bunbury, and the forms of *Pecopteris* show its near connection with the carbonaceous shales and sandstones of Scarborough; *Phyllotheca*, *Glossopteris*, and the narrow fronds of *Cyclopteris*, if M'Coy's figure† be truly of that genus, mark out the relation to the coal-beds of New South Wales, while *Tæniopteris magnifolia*, and sulcated stems in all respects corresponding with *Phyllotheca*, testify to the agreement with the Virginian carboniferous strata. These coincidences, some of which, as in the so-called *Asterophyllites?* and *Tæniopteris magnifolia*, seem to amount even to specific identity, along with the remarkable relations which the distant localities exhibit among themselves, form a network of proof, which, in my opinion, binds down all the various series of rocks to about the same epoch,—an epoch which the known position of the Stonesfield and Scarborough strata show to be Lower Oolitic.

Whether the Mángali sandstone is to be reckoned contemporaneous with these,—whether the two different kinds of strata there—the coarse thick-bedded upper and the fine fissile lower—are to be reckoned the equivalents of our A and B, is a question which observation in the field and a comparison of the respective fossils do not enable me to answer. The massive sandstone at Mángali, as has been said, is destitute of iron bands, and the inferior argillo-arenaceous strata are much redder than ours; and especially the organisms of the lower strata at the two places are very dissimilar. Here they are all vegetable, while there they are almost exclusively animal. Only one of the fossil plants at Mángali appears to us to bear a resemblance to anything found in this vicinity. At the same time, if any inference is to be derived from the succession of the rocks there, it is in favour of the idea that they are the counterparts of our A and B. And that they cannot in age be far removed from them is proved by a comparison, not of the Mángali fossils with others in this territory, but of both these with those across the Atlantic. Our investigations in the resemblances of the sandstone fossils show that the

* Professor Oldham states that there is considerable inconformability between those in Katták.—S. H.

† Ann. Mag. Nat. Hist. vol. xx. pl. ix. fig. 3.

Nágpur fossiliferous strata are connected with the Richmond carboniferous formation by *Tæniopteris magnifolia*, while the Mángali fossiliferous strata are still more closely linked to it by the discovery of what appear to be *Aspidiaria*, *Knorria*, and the interesting groups of large and small *Limnadiadæ*. Here, then, we perceive that the lower beds at both of these Indian localities bear a relation to the Virginian coal-measures, characterised by an apparent specific identity of fossils; and, though the genera of which the species seem to be identical are not the same in both cases, yet it is obvious, from the sort of *ex æquali* argument which we may be permitted to use, that these lower beds must stand pretty closely connected with each other. But I do not wish to push to an extreme reasoning on a point which the progress of investigation here may soon elucidate by finding the strata under consideration in juxtaposition. Meanwhile I consider myself warranted in asserting that our Mángali rocks cannot at all events be older than the Jurassic, if under that term the Lias is also included. Indeed the head of the Labyrinthodont tends to communicate to them a Triassic aspect; but if the Jurassic character of their abundant flora be taken as the real indication of the age of these rocks, we arrive at a conclusion which brings out the interesting fact that the family of Labyrinthodonts, instead of being confined to the Coal and Trias, survived (in the East) until the period of the Lower Oolite.

Regarding the age of our shale C, which there is every reason to believe underlies the coarse and fine sandstones A and B, I have little to say more than that it cannot be much older than these. The occurrence of worm-tracks, as well as of faint traces of *Phyllotheca*, will not allow me to consider it anything but part of the same Jurassic formation.

But, as I have endeavoured to show that the coal-measures of Burdwan are equivalents of our plant-bearing beds, and therefore belong to the Lower Oolitic group, it will be necessary to make a few remarks to establish the correctness of this view. On the age of the coal-measures of Bengal two opinions have been submitted to the public within the last four years:—one in 1850 by Dr. M'Clelland in his Geological Survey, and the other in the course of the present year by Dr. J. Hooker in his interesting Himalayan Journals.*

Dr. M'Clelland's sentiments, which in 1846 were very decided as to the true Palæozoic character of our eastern coal,† seem to have remained

[* This portion of the paragraph on the "Age of the Sandstone" has been remodelled since the reading of the Paper, so as to introduce the necessary references to the opinions published by Dr. J. D. Hooker in his most interesting work on the Himalayas.—June 14 and September 6, 1854.]

† "There cannot, however, be a doubt as to its belonging to the true coal formation, from the nature of the coal itself, as well as of the beds with which it is associated."—Secretary of

the same at the period of his more recent publication on the subject; for we find him in his Survey, while admitting the Oolitic age of some bluish-white indurated clays at Dubrajpore in the Rajmahal Hills, nevertheless placing the shales, sandstones, and seams of coal of Burdwan, and of Mussinia and Kottycoon in the Rajmahal Hills, as an intermediate formation, which he styles the "Coal-measure," between the Inferior Oolite mentioned above and what he supposes to be the "Old Red Sandstone." After deducting specimens of *Fucoides*, which I cannot, with the aid of his figures, distinguish from those of *Glossopteris*, there are seven genera, to which he refers as "Indian coal-measure fossils." Of these, four, viz. *Sphænophyllum*, *Poacites*, *Calamites*, and *Pecopteris*, he says, are "common to the coal-measures of Europe." In the conclusion which would naturally be drawn from this statement I cannot concur; and hence it is necessary to review the grounds on which it is made. The three genera not mentioned are *Zamites*, *Tæniopteris*, and *Glossopteris*. Of these, the first two are held to be well nigh characteristic of the Jurassic period, while the remaining genus, though unknown in Europe, must, from the circumstances in which it is shown to occur, now be acknowledged to be equally a Mesozoic plant. And with regard to the four genera specified, I do not suppose that Dr. Royle will assent to the identification of his *Trizygia* with *Sphænophyllum*; and, if any specimens of the genus *Calamites* had been preserved for description, I have little doubt they would have proved to belong to our "non-tuberculated class of opposite sulcated jointed stems," which abound in formations above the true coal-measures. The genera *Poacites* and *Pecopteris* I have found in our Jurassic strata, and a specimen of the latter here is so like one figured by M'Clelland that it is difficult to resist the conviction that they do belong to the same species. If to the evidence now adduced there be added that afforded by the occurrence of the peculiar plants *Vertebraria Indica*, *Trizygia speciosa*, &c. at Burdwan and Bhuwan, I think little probability will remain of the Bengal coal-formation being Palæozoic.

Dr. Hooker, in commenting on the opinion of Dr. M'Clelland, which he supposed to be in favour of the Oolitic age of the Burdwan coal-field, at the commencement of his first volume, endeavours to prove that no inference can be deduced from the plants discovered in those strata. In his second volume, however, he puts forth an opinion of his own, which, though not formerly enunciated in regard to the Burdwan series of rocks, may be gathered from his remarks on the carbonaceous shales near Punkabaree. On these shales there were "obscure

the Calcutta Coal Committee on the Coal of the Great Tenasserim River, in Committee's Report, p. 138. Calcutta, 1846.

impressions of Fern-leaves, of *Trizygia* and *Vertebraria*, both fossils characteristic of the Burdwan coal-field, but too imperfect to justify any conclusion as to the relation between these formations.* And then, in a foot-note, it is added, "these traces of fossils" (including a fragment of bone as well as vegetables) "are not sufficient to identify the formation with that of the Siwálik Hills of North-West India; but its contents, together with its strike, dip, and position relatively to the mountains, and its mineralogical character, incline me to suppose it may be similar." It may appear presumptuous in me to impugn the view of one who, from personal no less than hereditary claims, is entitled to the utmost respect on the subject of vegetable remains. I feel, however, that the learned author has been led away by his distrust of the evidence afforded by fragments of plants to rely on the more uncertain indications of mere lithological phænomena. Do strike, dip, &c. furnish us with such strong testimony on the question of age, that for their sake the Punkabaree shales are to be denied a place with the Burdwan beds which have Ferns, *Trizygia* and *Vertebraria*, and to be ranked with the Siwálik rocks, which, I believe, have none of the three? Or, if the carbonaceous strata at both places are allowed to be contemporaneous, are both to be classed as Miocene or Pliocene, when the Bhuwan shales, which like them exhibit "impressions of Fern-leaves, of *Trizygia*, and *Vertebraria*," represent sandstones whose numerous fossils, not to mention those of Burdwan itself, are decidedly not more recent than Jurassic?

It only remains to add, that the age of the dolomitized limestone cannot be expected to be determined by the evidence of fossils; but as, in other localities, it is not unfrequently found to alternate with the shale c, it may be set down as nearly coeval with it;—thus making the whole series of rocks from A to D to correspond with the lower members of the great Jurassic formation,—reaching perhaps from about the position of the Scarborough strata downwards into the Lias.

VIII. *Plutonic and Metamorphic Rocks.*—At the end of a paper which has already extended to such a length, it would be unbecoming to say much on this part of our subject. We have in the city of Nágpur, and many localities to the east of it, the usual combinations of gneiss and quartz rock, mica and hornblende schist, with massive granite. The peculiarity of the lastmentioned rock in the streets of the capital is, that it is generally a pegmatite, consisting of flesh-coloured crystals of felspar with quartz, disposed so as often to take the appearance of graphic granite. But very frequently it occurs with the felspar compact, in large white masses, which then have much the appearance of a pure dull porcelain. In Nágpur the most common rock is gneiss, passing into

* Himalayan Journals, vol. ii. p. 403.

mica schists. The former rock, when fresh, is quarried, though not extensively, for building, and, when disintegrated, for the repairing of the roads. But for both of these purposes respectively trap, in the two conditions mentioned, is preferred. Masses of white quartz appear here and there in the city, some with crystals of black schorl, and others with scales of gold-coloured mica. The range of plutonic hills on the west of Kámpti, which is indeed only a narrow prolongation of the great granitic district in the Wein Gangá basin to the east, has been thrown up by an eruption of granite corresponding nearly with the course of the Kolar. The massive rock which lies in the channel of the river, unlike that of Nágpur, is generally grey and very micaceous. Above it, forming the N. base of the range, lies mica schist, passing into granular schistose quartz, which is overlaid by a stratum of dark-grey, glistening, resinous quartz, and then by a considerable thickness of white quartz with scales of mica. This constitutes the ridge of the range for about its entire length from Waregaum to Gumtara, and with its snowy whiteness attracts attention from a great distance. At the northern base of the range, between the quartz and the dolomite of Korhadi, there are interposed some beds of granular quartzose rock, which has very much the appearance of being an altered sandstone; in which case it might be the representative in this part of the country of the "Tará sandstone." But throughout the field of crystalline limestone at Korhadi there are many eruptions of granite, which just rise to the surface without any intermediate metamorphic rocks at all. In some of those instances the granite is garnetiferous, and at its junction with the dolomite the latter, besides its usual ingredients of steatite and tremolite, is intermingled with mica. At Hályádoho, NE. of Umre*d*, mica-schist with garnets is quarried for pavements; it abounds along the course of the A'mb River. At Segaum various plutonic rocks rise from under the sandstone, and extend northwards to Karsingi. The first which appears in the north street of Segaum is syenite, in which the felspar and hornblende greatly preponderate over the quartz. About 300 yards to the north this is succeeded by another kind of syenite, in which red felspar is combined with a small proportion of quartz, and a large quantity of a green mineral (epidote or diallage ?). This rock (euphotide ?) seems to be massive, and, if we may judge from the fragments of it lying on the surface, is the prevailing rock for some miles. In an adjoining plutonic area, a little to the north, there is an extensive development of potstone at Jámbul Ghàt. The rich dark kind that possesses a dull metallic lustre has hitherto been reserved by Maráthá authority for the manufacture of idols; but the lighter coloured varieties, which are more common, occurring also at Dini near Rámpaili, and at Biroli on the Wein Gangá, near Tharorá, have been long used for fashioning into vessels. Stea-

titic schists of a pure white tint, with a few imbedded garnet crystals, occur at Kancri, on the Chulband river, and at various other localities east of the Wein Gangá. In many parts of this river's course, and in the Lánji Hills, hornblende rocks, both schistose and massive, abound. A coarse kind of corundum occurs at Pohorá in the Pergunna of Sáhangad*i*, on the south of the road from Nágpur to Ráyepur.

Metals.—Small quantities of gold are found near Lánji in the sands of the Son river, a tributary of the Wein Gangá. In some fragments of quartz rock on Nimá Hill, west of the Pech river, Colonel Jenkins found galena. Where this rock is associated with dolomite, as at Kumári, it contains manganese. But the principal ore which it yields is iron; this may be obtained in immense quantities in the province of Chándá, both on the east and west of the Wein Gangá. Near Dewalgaum, only three miles from the east bank of this navigable stream, which communicates by the Godávari with the Bay of Bengal, in the midst of a level country covered with jungle, there is a hill named Khandeshwar, consisting of strata tilted up at an angle of 60° or 70°, the dip being to the north. The summit of the hill is about 250 feet above the level of the plain, 100 feet being gradual ascent through jungle, and the remainder an abrupt wall of naked rock. The iron ore is for the most part specular, though many specimens possess polarity, and seem to be magnetic. It is on the surface of the slope that it is most valuable; but the whole mass, from an unknown depth under ground to the highest peak above it, is richly laden with metal. This single hill might furnish iron for the construction of all the railroads that shall ever be made in India, and with its abundance of fuel and cheapness of labour, and convenience of situation, it is admirably adapted for an export trade to every part of the country. But besides this locality, there are others in the neighbourhood which could each contribute an unlimited supply of the same indispensable metal. Among these may be mentioned Lohárá, Ogalpet, and Metápár, Bhánápur Mendá, and Gunjáwahi, which are all on the W. of the Wein Gangá; and at all of which places the ore seems to occur in quartz, and is sometimes granular, but for the most part compact. Unimportant crystals of it are scattered through the pegmatite of the capital. Notwithstanding that the specular ore is so abundant, there are many districts on the north of those already named where the hydrous oxide, in the shape of the heavier lumps of laterite, are selected for smelting by the poor natives, whose tools are anything but adapted for contending with the hard masses of the metamorphic matrix or gangue.

Age of the Plutonic and Metamorphic Rocks.—These evidently do not all belong to one and the same epoch. Colonel Jenkins observes that at Nayakund on the Pech, to the north of Nágpur, he met with "a grey granite, composed chiefly of whitish felspar in very large crystals," a

mass of which "was distinctly traversed three or four times by granite veins, accompanied by as many heaves." The granite of the veins was smaller-grained and redder the more recent it was, and, to the best of that officer's recollection, was destitute of mica. Without, however, more extensive artificial sections of the rocks in this neighbourhood than have ever been executed, I fear it will be difficult to fix the respective ages of the different eruptions. A cursory view of the question would lead to the supposition that the micaceous granite is more ancient than the pegmatite; but, in areas where both are presented in the vicinity of each other, the soundness of this view may be questioned, or at all events it appears to be impossible, in the present state of the country, to have it confirmed. The pegmatite of Nágpur city, which we have said is associated with gneiss, mica schist, and quartz with mica and with schorl, is evidently a very recent eruption, for it has not only converted much of the very highest member of the Jurassic sandstone into gneiss, but it has completely upheaved it. That the eruption, therefore, was posterior to that formation, there cannot be the slightest doubt. But it has sometimes occurred to me, though the observations of the most eminent Indian geologists are opposed to the thought, that this pegmatitic outburst may be subsequent even to our trap.

The section (Pl. VI. fig. 2) may throw some light on this doubtful point. In this section we have the overlying trap (*a*) occupying the two summits of Sitábaldi Hill, under it the tertiary fresh-water formation (*b*) and the intruded amygdaloidal trap (*c*) which has encroached on it. At the foot of the hill is the upper sandstone (*d*), which has been metamorphosed to a great extent by the gneiss (*e*), or rather by the pegmatite (*f*) beneath. On the north part of the hill the gneiss comes to the surface; but a little further north it is, together with the sandstone, overlaid by trap. This trap, which agrees with that overlying the tertiary beds in being nodular and poor in minerals, resembles in the very same respects the amygdaloid where it constitutes the superficial rock on the ascent. Proceeding in the same line, we find the trap cease and the sandstone upheaved. After this interruption the trap is again seen to be on the surface. Now the question arises: what is the reason that the trap is not found where the granite has thrown up the sandstone? The most obvious reply is, that once it was there, as it is seen on either side, but that by this eruption it was removed; in which case the plutonic rock would be of more recent origin than the volcanic. But, as there is the alternative of the latter never having been spread over the position of the former, and as this alternative is favoured by the examination of other localities, I content myself with merely submitting the case for determination, and stating that my latest observations lead me to believe that the trap is of later age than the granite. At all

events the section undoubtedly shows that the pegmatite and some of its accompanying gneiss are of an age subsequent to the upper sandstone. And yet in a layer of conglomerate contained in the red shale of Korhádi we meet with pebbles of undulated mica schist very like that which occurs in the present day between Surádi and Korhadi. Rocks of this character, then, whether we are right or wrong in suggesting their connection with any still existing, did exist before the deposition of the red shales.

Conclusion.—In tracing the geological history of this district from the facts that have been brought forward, we are made to feel that the early epochs are involved in the utmost obscurity. While in many other countries the records of what took place in Palæozoic times have been preserved in successive strata of the earth's crust, in the Dakhan they have been wholly obliterated. It is not until we come down to the Jurassic era that we meet with archives whose characters can be read. Then we find that Central India was covered by a large body of fresh water, which stretched southward into the Peninsula, and eastward into Bengal, while on the north and west it communicated by some narrow channel with the sea. On the shores of this lake earthworms crawled, and small reptiles (frogs) crept over the soft mud. In its pools sported flocks of little Entomostracans resembling the modern *Estheria*, mingled with which were Ganoid fishes and Labyrinthodonts. The streams which fed it brought down into its bed the *débris* of the plutonic and metamorphic rocks which then constituted the greater part of the dry land, and which were covered with an abundant vegetation of Ferns, most of them distinguished by the entireness of their fronds. Low-growing plants with grooved and jointed stems inhabited the marshes; and Conifers and other Dicotyledonous trees, with Palms, raised their heads aloft. Meanwhile plutonic action was going on, and strata, as they were formed, were shattered and reconstructed into a breccia; and finally an extensive outburst of granite elevated the bed of the lake and left it dry land. The sea now flowed at Pondicherry and Trichinopoly, depositing the cretaceous strata which are found there.

At the end of this epoch Central India suffered a depression, and was again covered by a vast lake, communicating with the sea, not towards Cutch as before, but in the neighbourhood of Rájámandri, to which the salt water had now advanced. When the lake had, during its appointed time, furnished an abode to its peculiar living creatures and plants, it was invaded by an immense outpouring of trap, which filled up its bed, and left Western and a great part of Central India a dreary waste of lava. But these basaltic steppes were ere long broken up. A second eruption of trap, not now coming to the surface, but forcing a passage

for itself under the newer lacustrine strata, lifted up the superincumbent mass in ranges of flat-topped hills. Since then, to the east, water has swept over the plutonic and sandstone rocks, and laid down quantities of transported materials impregnated with iron, and some time after there was deposited in the west a conglomerate, imbedding bones of huge mammals, and above it a stratum of brown clay, which immediately preceded the superficial deposits of the black and red soils.

P.S.—I have to acknowledge my great obligations to Lieutenant Colonel Alcock, of the Madras Artillery, and Dr. Leith and Mr. Carter, of Bombay, for assisting me in obtaining access to books (or extracts from them), of which I should otherwise have been deprived.

The map of the district described is coloured geologically from an excellent political map given in Rushton's Bengal and Agra Gazetteer for 1842. The formations between Chindwádá and the Mahádewa Hills are laid down from a sketch obligingly furnished to me by Mr. Sankey.

Description of the Cranium of a Labyrinthodont Reptile, Brachyops Laticeps, from Mángali, Central India. By Professor Owen, F.R.S., F.G.S. [With a Plate.]*

[Read June 21, 1854.]

The fossil obtained by the Rev. Messrs. Hislop and Hunter from the sandstone series of Mángali, about sixty miles to the south of Nágpur, and transmitted for my examination, is a considerable portion of a skull, wanting chiefly the tympanic pedicles and the lower jaw; it is imbedded in a block of bright brick-red compact stone, with its upper surface exposed. The skull (Pl. XII.) is broad, depressed, of an almost equilateral triangular form; the occipital border or plain rather exceeding in extent each lateral border, which borders converge with a slight convex curve to the rounded obtuse muzzle. The breadth of the occiput is 4 inches 9 lines, and the extent of each lateral border of the skull in a right line is 4 inches 6 lines. Most of the cranial bones are impressed by rather coarse grooves, radiating in each from a prominence which indicates the primitive centre of ossification; the intervening ridges being in some parts broken up by communicating grooves into tubercles. The orbits (*o*, *o*) are entire, of a moderate size, of a full oval form, and situated in the anterior half of the skull. The middle line of the upper surface of the skull is slightly depressed; at the upper and fore part of the skull on

* Reprinted from the Quarterly Journal of the Geological Society of London, vol. xi. part i. p. 37.—February, 1855.—Ed.

each side, there is a smooth continuous groove of a sigmoid form, with a strong curve, convex outwards anterior to the orbit, and with a less strong curve, convex inwards on the inner side of the orbit: between the orbit and the occiput there is on each side a shorter groove, extending from the exoccipital forwards and a little outwards to the postfrontal, where it bends more directly outwards and downwards behind the orbits: these grooves probably lodged large mucous canals. Portions of small, conical, pointed, subequal teeth extend in a single series along the alveolar border of the upper jaw (fig. 2, 21), from the muzzle, along the lateral borders of the fossil, to two-thirds of an inch behind the orbits. At the bases of some of these teeth may be discerned indentations converging from the periphery towards the centre of the dentine.

The entire orbits, closed below by a backward extension of the superior maxillary (21), and the connection of this bone by a malar (26) and squamosal (27) with the mastoid (8) and tympanic (28), forming a complete zygoma, prove that the fossil did not belong to the class of fishes; whilst the strong points of resemblance which the skull presented to the *Labyrinthodonts*—in its broad and very depressed figure (especially the great breadth of the occiput), in its external sculpturing (especially the number and position of the mucous grooves), in the form and position of the orbits, and in the characters of the teeth—led me to investigate the structure of the deeper part of the occiput which was concealed in the matrix, for the more decisive character which that part of the cranium affords of the batrachian affinities of the singular reptiles, to which the Mángali skull seemed by its more obvious characters to be most closely allied.

I was gratified by finding that the occipital bone (which, like the rest of the skull, was distinguished from the red matrix by its yellow colour) terminated posteriorly in two well-defined subdepressed convex condyles, 2, 2, not so close together as in the great *Labyrinthodon salamandroïdes* (*Mastodonsaurus* of Jaeger), but separated as in the *Trematosaurus* of Burmeister.* A part of the broad atlas (*a*) was found in connection with these condyles.

The superoccipital region is formed by a pair of bones, 3,3, each with a slightly prominent centre at the angle between the horizontal and backwardly-sloping part of the occiput: they may represent a divided superoccipital bone, but I cannot trace a suture separating them from the exoccipitals supporting the condyles, where it is represented by Burmeister in the *Trematosaurus*.

External to these is a large bone with a well-marked prominent centre, from which the grooves of the outer surface radiate: on the left

* Die Labyrinthodonten, 4to, 1840, part i. pl. 1.

side, a part of the tympanic remains in connection with this bone, which I regard as the mastoid, 8, which bone occupies a similar position in the *Labyrinthodonts.* The parietal bones, 7, 7, continue the cranial walls in advance of the superoccipitals, and show a small oval vacuity in their median suture—the "foramen parietale," as in the *Trematosaurus;* the foramen is situated near the hinder part of the suture; an accessory parietal 7*, extends outwards from the hinder part of the main body of the bone on each side, to the angle between the superoccipital and mastoid. Traces of a suture seem to show this to be a dismemberment of the parietal: it occupies the place of the bone marked *n*, and called "os temporale squamosum," in the abovecited figure of the *Trematosaurus;* but the true squamosal is always anterior and external to the mastoid in the reptiles in which it is unequivocally present; and it is restricted to its zygomatic place and functions, not becoming a proper cranial bone until the mammalian type is reached. The precise boundaries of the frontal, 7, and the sutures dividing it from the nasals and prefrontals cannot be traced, the skull being abraded at this part. The postfrontals, 12, have their centre as well marked and prominent as in the mastoids, and extend to those bones from the outer and back parts of the orbits. Traces of the malar, 26, and true squamosal, 27, may be discerned on the left side, extending from the slender maxillary beneath the postfrontal to the tympanic, 28, beneath the mastoid, 8. The bone here called "postfrontal" is the "os orbitale posterius," *i*, of Burmeister, and the name "os frontal posterius" is restricted in the abovecited figure of the *Trematosaurus* to a supplementary bone which is interposed in that Labyrinthodont, as in the present, between the bone marked 12, the parietal 7, and frontal 9, where it forms the inner half of the back part of the orbit. This bone appears to me to be a dismemberment of an unusually developed postfrontal, and both it and the supernumerary bone, 7*, are remarkable departures from the normal cranial structure, characteristic of some, if not of all of the Labyrinthodont batrachians. The marked departure in the form and proportions of the present cranium from those of the equally well-preserved specimens of European Labyrinthodonts leads me to the conclusion that the Mángali species indicates a distinct subgenus in that group of Reptiles, and I propose to designate the species so represented by the term '*Brachyops*† *laticeps*,' indicative of its peculiar proportions.

Although the abraded and otherwise mutilated state of the skull of the *Brachyops* is such as to prevent my giving a more extended anatomical description of it, and determining more precisely and satis-

† From βραχὺς, *short;* ὤψ, *face;* in reference to the shortness of the facial part of the skull anterior to the orbits.

factorily the boundaries and homologies of the constituent bones, it nevertheless permits so many characters of the skull of the Labyrinthodont Batrachia to be determined, as can leave no reasonable doubt of its true nature and affinities; and thus the results chiefly required by the geologist, in reference to the probable age of the stratum in which this fossil is imbedded, may have been attained.*

DESCRIPTION OF PLATE XII.

Fig. 1. Upper view of the skull of the *Brachyops*, nat. size.
2. Side view of the same, nat. size.

On the Connection of the Umret Coal-beds with the Plant-beds of Nágpur; and of both with those of Burdwan. By the Rev. S. Hislop. Communicated by J. C. Moore, Esq., Sec. G. S.†

[Read June 13, 1855.]

In the observations on the Jurassic Formation of the Nágpur Territory, which I had the honour to submit to your Society, I showed that it consisted of four members in the following descending order‡: A, thick-bedded coarse ferruginous sandstone, with a few stems of trees; B,

* When a family of animals is of considerable extent, it becomes necessary to indicate to what division of it a particular genus belongs. This is doubly requisite, if a question of geological age depends on the determination of the point. Such happens to be the case in regard to the *Brachyops* described above by our great comparative anatomist. It is well known that *Labyrinthodontidæ* have been found in more than one formation. The British remains of this family, which were formerly supposed to be Triassic and therefore Mesozoic, are now, in consequence of more accurate observation of the strata, assigned to the Permian formation or Palæozoic epoch. But there are still, in the Keuper of Germany, genera whose claim to be regarded as Mesozoic has not yet been disputed. Among these there is one, named by Von Meyer *Metopies*, which he includes in his subfamily of *Prosthophthalmi*, from its having the orbit of the eye situated nearer the muzzle than the neck. Now the *Brachyops* is remarkable for this peculiarity, and therefore ought to be classed under the *Prosthophthalmi* of the Keuper, and not with the Permian Labyrinthodonts, whose eyes are placed either in the middle of the *semicranium* or behind it. These observations, which in substance I communicated to the London Geological Society, along with the specimen which suggested them, have not been referred to by Professor Owen; but I call attention to them here, as I shall have occasion to make use of them in a subsequent note, when I come to sum up the arguments which, in my opinion, tend to prove the Jurassic age of the Mángali and associated rocks.—*Note by the Rev. S. Hislop, August* 1856.

† Reprinted from the Quarterly Journal of the Geological Society of London, vol. xi. part i. p. 555, November 1855.—Ed.

‡ Vide this vol. p. 273.—Ed.

laminated sandstone, exceedingly rich in vegetable remains: c, clay-shales, of various colours, in which are found the traces of reptiles and worms; and D, limestone, which within our area is generally crystallised from its contact with plutonic rocks. At the time of penning these remarks, not having had an opportunity of inspecting any of our Indian coal-measures, I was inclined to regard them as the equivalents of our argillaceous strata marked c; but having recently enjoyed this privilege, while out on a mission tour with my friend the Rev. R. Hunter, I propose to communicate the modifications which have, in consequence, been wrought on previously-formed views.

Our tour extended about 120 miles NNW. of the city of Nágpur,—a distance which carried us past the carbonaceous strata near Umret, as far as the bituminous shales at the south base of the Pachma*d*i or Mahádewa Hills. These localities had both been visited by Dr. Jerdon and Lieutenant Sankey in 1852, and the results of their investigations have been laid before your Society.*

The coal-field of Umret is about five miles north of the village, near a small hamlet dignified with the name of Bari, or Great, Barkoi, to distinguish it from Chhoti, or Little, Barkoi, which lies three-quarters of a mile to the south. Leaving Umret, the traveller passes over granite for about a mile, when he begins to ascend trap-hills, which continue, with only a slight reappearance of plutonic rock in the low ground near Tawari, until within three-quarters of a mile of Chhoti Barkoi, where they end in an abrupt descent, at the foot of which there emerge beds of sandstone, that constitute the surface rock to the rivulet at Bari Barkoi. This stream has cut a passage through the sandstone, and laid bare the dark-coloured strata underneath, which are seen to dip at an angle of 5° to the WSW., the direction in which the water flows. The exposure displays the following succession: overlying sandstone, about 50 feet thick; coal, 1½ or 2 feet; argillaceous shale, 3 feet; bituminous shale, 1 foot; arenaceous and micaceous shale, 3 feet; and white sandstone, depth unknown.

On observing the strata and the order in which they occurred, I remarked to Mr. Hunter, that the shale would probably turn out to be the representative of the fissile sandstone, abounding in fossils, that is so well developed at Kámpti, Silewá*d*á, Bokhárá, Bharatwá*d*á, &c. In hazarding this conjecture, I took it for granted that the overlying rock was the common sandstone of this country, which is for the most part traversed by iron bands. Search having been made, the iron bands, though not of the typical character, were discovered. So far the hypothesis was confirmed.

* Quart. Journ. Geol. Soc. vol. x. p. 55.

Additional light was thrown on it by examining the circumstances under which the argillaceous and bituminous shales are met with at the Mahádewas. The sandstone forming the mass of that mountain range must be about 2,000 feet thick, and presents a line of bold mural crags, extending E. and W. for upwards of twenty-five miles. The front of the precipice is towards the south, while the strata dip at an angle of 5° to the north, or, more correctly, NNE. However much the thickness of these arenaceous beds exceeds that of the ferruginous sandstone in the immediate neighbourhood of Nágpur, there can be no doubt that both rocks are the same, as both possess the same iron bands, which I consider positive evidence of identity, when they do occur; though their absence may not be conclusive as to dissimilarity. Under the sandstone, there are about 8 feet of green shales, becoming more micaceous and laminated below, and succeeded for about 3 feet by bituminous shale, which disappears under the surface of the ground. Unlike Barkoi, there is no seam of coal to be seen, but the tendency to it in the bituminous shale is manifest enough; and, indeed, this latter bed, as I shall endeavour to show, when I come to speak of the organic remains, is palæontologically a part of our Indian carboniferous strata.

Here, then, at Barkoi and the Mahádewas, as well as near Nágpur, we have the same thick-bedded iron-banded sandstone overlying in the last mentioned locality more fissile strata of a somewhat similar material; but at the former two places, superposed on argillaceous and carbonaceous or bituminous shales. Are then the *lower* beds also of the same age in all three localities? Of the contemporaneity of the inferior strata at Barkoi and the Mahádewas there cannot be two opinions; but as those in our immediate neighbourhood differ in colour, and to a considerable extent in composition, some hesitation may be felt in including them in the identification. It may be supposed that there is a deficiency in the one district, which is supplied in the other.

Now it may help to remove doubt to mention that, even in this vicinity (Nágpur), where the lower strata are generally of a whitish hue, they present in their higher portion a certain quantity of clay, which becomes less and less as we descend, until at last, as in the underlying beds at Barkoi, we arrive at pure sand. And, to complete the analogy in regard to composition, it may be added, that in a particular spot at Bokhárá, six miles N. of Nágpur, the higher laminæ now referred to exhibit not only the argillaceous mixture, but an approximation to the carbonaceous colour, being quite brown through the amount of comminuted vegetable matter which they contain.

But for direct proof of identity in age, an appeal must be made to the fossil contents of the strata under comparison. At Barkoi we found

the following genera: *Glossopteris* and *Cyclopteris*, with *Phyllotheca*, *Vertebraria*, and other stems, and a variety of fruits or seeds. At the Mahádewas, during the very hurried visit which we made to that locality, we discovered *Glossopteris*, *Phyllotheca*, *Vertebraria*, and fruits or seeds; besides which, I believe, our friend Mr. Sankey had previously brought to light specimens of *Pecopteris*, *Sphenopteris*, and *Trizygia*.

In regard to the Barkoi plants, I think there is scarcely one that cannot be specifically matched with some one from the laminated argillaceous sandstone in the vicinity of Nágpur. Of the genus *Glossopteris*, the bituminous shale furnished several species; but among them there is not one that strikes me as not having been observed before in our arenaceous strata. The *Cyclopteris* of Barkoi exactly agrees with that of Baratw*ádá*, both being oblong-cuneate, and characterised by the same venation. The most abundant *Phyllotheca* at Barkoi is one with 10 sulci, which is also the one most frequently discovered near Nágpur. Of *Vertebraria*, there does not appear to be more than a single species, though Royle* has formed a *V. radiata* from a transverse section of the stem of his, *V. Indica*, and M'Coy† has added another species, *V. Australis* from New South Wales, because there is a slight difference in the radiations of his transverse section from those of Royle's.

Taking the *Vertebraria* found at Barkoi as belonging to the only species hitherto discovered either in India or Australia, it is satisfactory to ascertain, that it is just as abundant in all the localities of our sandstone as in the coal-formation of Barkoi. Besides the *Vertebraria*, there is another stem common at Barkoi, which has its exact counterpart nearer Nágpur. It is undescribed, but may be distinguished by its nearly oppo-

* Illustrations of the Botany, &c. of the Himalayan Mountains. When I formerly referred (Journ. No. 43, p. 371, &c. and MS. account of the fossil plants) to this remarkable genus of plants, I had not in my possession a specimen from the Indian coal-shales. The recent examination of many such has served to increase in my mind the conviction that its character has been misunderstood. Its smaller branches are somewhat slender and apparently winged. Sometimes they are found lying along the plane of the laminæ,—at other times running across it. When a branch is discovered in the former situation, it is found to be split in two halves, with the wings that lie in conformity with the lamination stretched at their full breadth, while those that lie at an angle with it are, as it were, fore-shortened. In this case there is no trace of radiation. But when a branch is found running across the laminæ, as often happens, all the wings have equal room to retain their form, and hence the radiated appearance. The number of the radii or wings differs in specimens which I have examined from the same locality, and, as I believe, in portions of the same plant. A similar want of uniformity in this respect is perceptible in the specimens figured by Royle. That there is any such thing as dichotomous-veined foliage between the radii does not appear from the shale specimens that have fallen under my notice. On the contrary, they seem to be wholly destitute of leaves. But there is every reason to think that our sandstone specimens possess these appendages, and that they are of a narrow linear shape, like those of the *Phyllotheca*.

† Ann. and Mag. Nat. Hist. vol. xx. p. 147.

site leaf-scars, and occurs plentifully in the laminated sandstone of Silewádá. The fruits or seeds from Barkoi I have not at present the means of comparing with those of Kámpti. One of them, however, may be easily recognised as identical with a fruit or seed lately met with at Bharatwádá.

Between the vegetable remains of the Mahádewas and those of our laminated sandstone, a like comparison might be instituted. If, for example, Mr. Sankey's *Pecopteris* from that locality agreed, as my memory suggests, with one figured by M'Clelland,* then it must have corresponded with one that occurs at Kámpti. The *Vertebraria*, both at the Mahádewas and near Nágpur, might be proved to be identical, and a general resemblance pointed out in regard to *Glossopteris*, *Phyllotheca*, and the fruits or seeds. But after the statements of the previous paragraph, it is scarcely necessary to enlarge.

From the above numerous coincidences, it may be inferred that our laminated sandstone is the equivalent of the carbonaceous and bituminous shales in the north of this territory. It follows, as a matter of course, that the position of the coal-measures is among the beds immediately underneath the ferruginous sandstone (A).

If we look beyond this province, we shall find this view amply confirmed. The account given by Dr. Walker† of the discovery of fragments of coal at Kotá, in the Nizam's dominions, would lead to the belief that the carbonaceous and bituminous shales which he noticed were above the highest bed of argillaceous limestone. But whether this may have been the case or not, is of little consequence; as all I contend for is, that they are near the base of the iron-banded sandstone —a position which must at once be assigned them, when we take into account their relation to the surrounding hills at Kotá.‡ The succession at Duntimnapilly,§ according to the same writer, seems to have been,—anthracite, carbonaceous sandstone, and micaceous sandstone. What the rock, 15 feet thick, above the anthracite was, he does not mention. But it is worthy of remark, that the carbonaceous and micaceous sandstone, into which the anthracite passes downwards, bear a great resemblance to the strata underlying the coal-seam at Barkoi, and appear to coincide with the 8 feet of laminated sandstone mentioned by the late Dr. T. L. Bell in his detailed description of the rocks bored through at Kotá. It is to this lamented officer that we owe the best materials for comparing the coal-measures on the banks of the Pranhitá with those in the north of Nágpur. The section with which he has furnished us is,—sandstone (iron-banded), from 50 to 500 feet; argilla-

* Report of Geological Survey for 1848-49.

† Beng. Asiat. Soc. Journ. vol. x. p. 342.

‡ Quart. Journ. Geol. Soc. vol. x. p. 374, and note.

§ Beng. Asiat. Soc. Journ. vol. x. p. 344.

ceous limestone, 9 feet; bituminous shale, three-quarters of an inch; then argillaceous limestone, bituminous shale, and limestone again, which passes into the laminated sandstone alluded to above. Without quoting further from this list of strata, which has already been published in the Journal* of the Society, I may mention that the *bituminous* shale at Kotá, though to a considerable extent interstratified with argillaceous limestone, &c., is found only in the upper half, while *argillaceous* shales and limestone preponderate in the lower half. Limestone, according to the most recent information received from Dr. Bell, was the lowest rock reached after passing through 27 feet of red clay-shale.

Again, at Palamow, the first beds that Mr. Homfray† came upon under a mass of sandstone, 150 to 200 feet thick, were shale and coal, resting upon 30 feet of sandstone, in which we may again trace a similarity to the coal-field at Barkoi. Such also is the order of the strata at Singrá, as given by Mr. Homfray. Mr. Carter, in his admirable "Summary of the Geology of India,"‡ shows that Jacquemont found small layers of anthracite between the strata of compact limestone which immediately underlie the Panná sandstone. According to Franklin,§ in all the glens connected with the Panná range, particularly in that of the Bágin river, black bituminous shale crops out from beneath the sandstone. Mr. Osborne's observations|| prove that under the sandstone of Umla Ghàt there is shale with exudations of petroleum, which is succeeded below by alternate beds of sandstone and shale, limestone lying under all.

Thus we see that south and north-east of this territory, as well as within its limits, the carbonaceous and bituminous shales may be said immediately to underlie the ferruginous sandstone. It is difficult to comprehend the Burdwan coal-field in our comparison, for it seems to lie in a basin, and the carboniferous strata rise to the surface without any superincumbent sandstone. But the connection, which cannot be established lithologically, may be rendered very manifest by the evidence of fossils. Species of *Trizygia*, *Vertebraria*, *Glossopteris*, and *Pecopteris* are common to the shales of Burdwan and those of the Mahádewas. And, although Dr. M'Clelland has professedly figured no *Phyllotheca*, or Calamite, as he would name it, from Bengal, yet there can be little doubt that what he calls *Poacites minor* ¶ is identical, wanting the joint, with one of our Phyllothecas found both at the Mahádewas and Kámpti, and specifically distinguished by the possession of 8 sulci.

* Quart Journ. Geol. Soc. vol. viii. p. 231; vol. ix. p. 351; and vol. x. p. 374.

† Beng. Asiat. Soc. Journ. vol. x. p. 374.

‡ Bomb. Br. Royal Asiat. Soc. Journ. No. 19, p. 204.

§ Asiat. Res. vol. xviii. part i. p. 103.

|| Beng. Asiat. Soc. Journ. vol. vii. p. 843.

¶ Geol. Survey, Tab. xvii. fig. 4, with the description at p. 55.

I am not certain, though I am disposed to think, that the *Poacites muricata** of the same author is the unfurrowed stem, with nearly opposite leaf-scars, described above, p. 295, as common in the shale of Barkoi, and the laminated sandstone of Silewá*dá*. The breadth and rigid appearance of our specimen are exactly the same as in M'Clelland's figure, and there is occasionally on them a fine longitudinal striation, which might be taken for the venation of an endogenous leaf.

Subjoined is the succession, from above, of our Indian fresh-water† oolitic formation, according to the view taken in this paper.

I. *Upper Sandstone Series; called by Mr. Carter the "Panná [Punna] Sandstone."*

In general, coarse and thick-bedded; sometimes friable, and white, variegated with red blotches; at other times hard and of a rusty colour, traversed by iron bands. Contains a few stems of trees about the base. Thickness at Nágpur 25 feet; at the Mahádewa Hills upwards of 2,000 feet.

II. *Laminated Series; the same as Mr. Carter's "Kattrá Shales."*

1. Either arenaceous, carbonaceous, or bituminous. The arenaceous strata more or less mixed with clay and mica; laminated and abounding in fossils above, and gradually becoming coarser, thicker bedded, and more destitute of organic remains below. The carbonaceous or bituminous shales are the equivalents of the laminated fossiliferous sandstone just mentioned. Though occasionally alternating with argillaceous limestone, they for the most part pass into micaceous or coarse sandstone. Thickness from 300 feet in the Nágpur territory, to 2,000 feet in Bengal.

2. Argillaceous shales, green, red, blue, and more rarely white, in some localities alternating with argillaceous limestone. Contains the traces of reptiles and worms. Thickness about Nágpur 80 feet, though much greater in the Bandárá district to the east

3. Limestone, sometimes compact, but often crystalline and dolomitic. Near Nágpur 100 feet, at Moodelaity 310 feet thick.

From the above arrangement of the laminated series, it will be seen there is a difficulty in disposing of the limestone. Beds of it in some districts of India alternate with our No. 2, and even with No. 1. At Moodelaity, where the latter appears to be wanting, the whole mass of it is said to overlie the argillaceous shales. I have followed the order as it is within this territory, where the limestone is most frequently crystalline, while the red shale, lying above it, has suffered no change from heat. This I am disposed to consider the typical order

* Geol. Survey, Tab. xiv. fig. 6.

† I here say nothing of the oolitic strata in Cutch, as they are obviously marine.

of succession among our "Fresh-water Oolites." At Kotá, though the calcareous and bituminous beds are interstratified to a certain extent, yet the greater part of the latter are found above, and of the former below. Newbold, who gives us the superposition at Moodelaity, embodies his views of the order of stratification throughout Southern India in these words:—" The limestone occupies, with few exceptions, the lowest position in the sections afforded by the great lines of drainage of these tracts, and in places where the superincumbent strata have been stripped off. Next in order of superposition come calcareous shales, mingled with much argillaceous matter, then argillaceous shales and slates, sandstone, siliceous and arenaceous schists, quartzose rock, and sandstone conglomerate."* In some parts of Bundlekhand the limestone occupies a high position: but, as we have had occasion to notice before, at Bagin the bituminous shale lies above the greater part of it. In the coal-fields of Bengal calcareous strata appear to be wholly wanting.

To complete the catalogue of our Indian† Jurassic Formation, I might here add—

III. *Lower Sandstone Series.*

This is developed at Moodelaity and in Bundlekhand, and has received from Mr. Carter the name of the "Tárá Sandstone"; but, as it does not occur within our area, except perhaps in the form of gneiss, mica-schist, and other metamorphic rocks, underlying our crystallized limestone, I forbear to enter on the consideration of it at present.

* Roy. Asiat. Soc. Journ. vol. viii. p. 160.

† In the beginning of 1853, when I first published my sentiments on the sandstone and associated strata of Nágpur, I was under the impression that they were all related conformably to each other; and hence, though I made a distinction between the thick-bedded sandstone above and the plant-bearing argillaceous sandstone beneath, and again between the latter and the underlying shales, and though I showed that plutonic agency had been at work in the intervals between some of these, yet it did not occur to me to doubt that both the highest and the lowest were of the same general age as the intermediate strata. I have since learned, from Mr. A. Schlagintweit, that the sandstone and inferior shales of Southern India are unconformable; and more recently I have been informed, by Professor Oldham, that there is a considerable difference in inclination among the rocks of the Katták coal-field, and especially between those corresponding to our upper sandstone and our argillaceous and carbonaceous beds. As this information could scarcely have been elicited from the appearances presented by the rocks of Central India, it is with gratitude that I hail the light arising from other quarters. But it now becomes a duty to inquire how far this discovery modifies the arrangement proposed for our strata three years ago. To me it appears its effect is not great.

It is to be borne in mind that the period when the rocks under consideration were deposited was just the period when plutonic action was most frequent. If granite disturbed our plant-beds before the deposition on them of the upper sandstone, we know that it also intruded on the latter strata, showing that they were in existence before plutonic agency had spent its force, and that probably the interval which elapsed between the two eruptions was not so great as to admit of a change of formation.

But there is evidence, perhaps, more direct. Our upper sandstone is unquestionably the same as that which is found on the banks of the Pranhítá and Godávari. Now it was in the conglomerate, or highest part, of this sandstone, that the late Dr. T. L. Bell discovered his reptilian remains, which Professor Owen believed to agree best with the structure of the Teleosaurus and Amphicœlian Crocodiles,—animals which generally occur in the Jurassic formation.

With regard to the age of the underlying fossiliferous rocks, I adhere to the view which I have always entertained, since I discovered in them the first of our large assortment of ancient organisms. True, the majority of these are vegetable remains; but I see not why their evidence on that account is to be slighted, provided the specimens are entire, and present the parts on which a correct classification may be founded. Are not plants characteristic of climate in their distribution over the earth's surface, as well as animals? And are not the former characteristic of eras in their range through the earth's crust, as well as the latter? I admit that the ancient Flora has lost many characters which aid in the classification of existing species; but so has the ancient Fauna. I acknowledge, in reference to Ferns, whose essential parts are, perhaps, best capable of preservation, that some genera have existed through many geological changes; but the same objection may be brought with greater force against some kinds of marine shells. In these and other respects, I can perceive little or no difference in value, between the evidence of vegetable and animal remains, if only equal caution is used in both cases in their classification. Now those of our plants, whose congeners have been described before, though not examined in the most favourable circumstances for accuracy, will be found, I believe, upon the whole, to be corrrectly named. The doubt does not occur here, but at a more advauced stage of the inquiry. It is not that our specimens assigned to the genera *Glossopteris* and *Tæniopteris, Vertebraria* and *Phyllotheca*, may turn out not to belong to these genera; but, admitting that there has been no mistake in the identification, it is still held to be problematical what conclusion is to be drawn from the occurrence of such kinds of plants in the rocks of Central India. To these questions I have, in the preceding papers, attempted a reply. I may be permitted to add a few remarks on the evidence from our ancient Fauna.

To render this testimony available, it is necessary to point out the relation between the argillaceous sandstone of Kámpti with its carbonaceous equivaleut at the Mahádewas which have afforded chiefly plants, and the fissile strata of Mángali with the bituminous shales of Kota, which have furnished principally animal organisms. Now the succession of upper thick-bedded and under thin-bedded strata is the same at all these places, and favours the presumption that the rocks at all, are identical. Then, the existence of bituminous beds at Kotá the site of ichthyolites, as well as at the Mahádewas and other localities for our vegetable remains, increases the evidence for the identity of the strata at these places and also at Mángali, where, though there is no trace of coal, the character of the fish-scales suggests the connection with Kotá. That the ferns, which are so common in the argillaceous sandstone of Silewádá, have not yet been found at Mángali is no great difficulty, when it is borne in mind how limited have been the investigations in the latter strata, and when it is remembered that, while most of the quarries even in the former abound in ferns, one is entirely destitute of them, though it is remarkable for the variety of its fossil stems. And although the Mángali fossil beds cannot, as regards fossils, be directly compared with the fern-bearing ones in the vicinity of Nágpur, yet, as has been suggested at p. 377, they may be mediately compared through the carboniferous formation of Virginia, which contains in itself, in the closest combination, the fossils of both these localities, proving that in America at least they existed together. It is to be wished that the nature of the terrestrial vegetation, which has left its impressions on the *Lepidotus* slabs of Kotá, were more particularly defined, for then we might discover in it some common term for estimating the contemporaneousness of the rocks with those in this Province. As it is, however, I think an object for comparison may be conjectured. A few feet under the ichthyolite strata at Kotá there lies laminated sandstone, from which Dr. Bell procured leaves which he was disposed to consider dicotyledonous. Now, as hitherto no true leaves of exo-

genous plants have been described from strata so low as the Lias or Oolite, it may be allowed me to suggest that the vegetable impressions in question, presenting, as they must have done, a well-defined and entire outline, and at the same time a distinct reticulate venation, were probably not leaves, but the anostomosing and simple fronds of some species of *Glossopteris*. Taking the whole of these circumstances into account, I conceive myself warranted in concluding that the strata immediately underlying the thick-bedded sandstone in the three places referred to have all been deposited at the same period.

And now we are in a position to make use of the evidence from animal remains. In the Kotá fissile strata all the ichthyolites, which have been found, have Homocercal tails, and, on the authority of Sir P. Egerton, belong to Liassic or Oolitic genera. Again, in the Mángali argillaceous sandstone not only do our *Estheriæ* resemble those of the Virginian Oolite, and our scattered fish-scales exuviæ such as occur in Jurassic strata, but even the *Brachyops*, which at first sight is apt to puzzle, is, as I have endeavoured to show, a Mesozoic form of Labyrinthodont. As it is in the Keuper of Würtemberg that we meet with the most nearly allied genus, it is surely easier to refer our Mángali reptile to the Lias, which in Europe immediately overlies the Keuper, than to carry it into the more distant Permian over the line separating Mesozoic from Palæozoic organisms. The red shale at Korhádi, by its position under the plant-beds, when compared with the clayey strata found in similar circumstances at Kotá, affords additional proof, if any were wanting, of the identity of the superior fissile beds at both places. But by its animal remains it also strengthens the evidence which I have given above of the Jurassic age of the whole series. Tracks of Annelids seem to be rare in ancient formations. Many of the so-called specimens are now reckoned Cololites of fishes. The marks of well-ascertained genera, of the shape and habits of the earthworm, apparently occur first in the Lower Jura rocks. And as the traces on the Korhádi shale most nearly resemble those of that familiar Annelid, we may legitimately infer that the formation in which they are met with is Jurassic.

Combining the different parts of this evidence from animal remains, we perceive that the Lias or Oolite is the age for our laminated sandstones and bituminous or carbonaceous shales, which is pointed out by all, with the exception of *Brachyops*, which, however, is altogether in favour of a Mesozoic epoch. No countenance whatever can I find in our ancient Fauna to the view that any of the strata in question are contemporaneous with the Permian or carboniferous system.

Here we might conclude, had we not to encounter a difficulty from Australia.—In that land of natural paradoxes, it appears, from the statements of the most competent witnesses, that plants, which occur in Indian rocks with animals of Mesozoic forms, have been imbedded with animals of Palæozoic affinities. Whether, then, as it has been forcibly put to me by Professor Oldham, are we to hold, that certain Palæozoic organisms survived to Mesozoic times in Australia, or that certain Mesozoic organisms began there and here as early as Palæozoic times? After the best consideration that I have been able to give this question, I have been led to accept the former alternative. It is not, however, on account of the fact that the fossils discovered in such ambiguous circumstances belong exclusively to the vegetable kingdom; for I believe that their evidence is not to be disregarded any more than that of animals. No, it is because I have endeavoured to allow full effect to their testimony, and to appreciate the value of their conflicting teachings, that I have arrived at the conclusion that, even without taking our animal remains into account at all, but on the authority of our old-world plants alone, the rocks under discussion ought to be looked on as Jurassic.

For what are the plants, which, from their being discovered in the Australian coal-field, have come to be viewed of such doubtful age, when found in our Indian strata? They are (I quote from memory), *Sphenopteris*, *Pecopteris*, *Glossopteris*, *Vertebraria*, and *Phyllotheca*. Of these the first two, number species in the Oolite of Europe most nearly resembling those in the beds of Australia. And the last, though hitherto not recognised as Phyllotheca, occurs, I have little doubt, in the Jurassic coal of Virginia as well as in the carbonaceous strata of New South Wales. These three genera, then, are to be disposed of by simply letting their testimony in the West

neutralise their evidence at the Antipodes. Only two genera, if I am not mistaken, now remain, viz. *Glossopteris* and *Vertebraria*, which have not been discovered in Europe or America, but are peculiar to India and Australia. These, as met with in this country, in the absence of proof to the contrary, we shall, on the ground of their association in New South Wales, in the mean time presume to be in favour of the Palæozoic age of their imbedding strata. But, to set over against them, we have a preponderance of acknowledged and characteristic Jurassic genera, found not in a basin whose relations have yet to be ascertained, like that of Newcastle and Hawkesbury in the Southern Hemisphere, but in the Oolite of England, having the Palæozoic rocks beneath, and forming part of the most complete geological series in the world. There is first, the *Tæniopteris* of Kámpti, Rajmahál, and the Damúda, in which we see the connection with the slate of Stonesfield, as we do again in the *seed-vessels* of this Province; then there is the disc-bearing *Asterophyllites*, or whatever it may be called, of Silewádá, which is scarcely distinguishable from that at Scarborough; and lastly, there are the *Cycadaceæ* of the two Bengal sites, which suggest the relation with the two English localities. When all this amount of evidence is compared with that of the two genera specified above, I think it will be admitted that, even confining our view to vegetable remains, the probability is greatly on the side of a Jurassic age.

But when to this we add the testimony of the animal remains, which, as I have shown before, is all in favour of a Mesozoic epoch, it appears to me that little doubt will remain of the correctness of the view, which in 1853 I advocated, regarding the age of our argillaceous sandstone, and its equivalent, the Indian coal.

I may only add, that, if we are bound to sum up for the Jurassie age of those strata, it is easy to perceive how even one of the two genera of plants that were presumed to bear evidence on the other side, though, I believe, unknown in the Mesozoic formations of the West, does, nevertheless, when ranged with all the other simple fronded ferns, which we discover in our Indian rocks, and which, out of India, numerically culminate in the Oolite, admirably harmonize with this conclusion. And deducting Glossopteris, with its many species, from the Palæozoic side of the question, and adding it to the other, there will be left the single genus *Vertebraria*, with its solitary species, of which we can give no explanation on the hypothesis that the rocks which we have been considering belong to the Lias or Lower Oolites.—S. H.

Nagpur, August, 1856.

On a Fossil Fish from the Table-land of the Deccan, in the Peninsula of India. By Colonel Sykes, F.R.S., G.S. *With a Description of the Specimens*, by Sir P. De M. G. Egerton, F.R.S., G.S.*

General Fraser, the British Minister at the Court of the Nizam at Hyderabad, in a letter to me, dated the 31st July 1850, mentioned his having transmitted some specimens of fossilfish, with impressions of leaves, in a matrix which Dr. Walker, whom General Fraser had employed in Statistical and Natural History researches in the Nizam's territories, considered as appertaining to a coal-formation. General

* Reprinted from the Quarterly Journal of the Geological Society of London, vol. vii. part i. p. 272.—Ed.

Fraser had previously caused specimens to be sent to the Asiatic Society of Calcutta; but the reports upon them not satisfying Dr. Walker, a second series of the specimens were sent to me by General Fraser, with a request that I would ascertain their possible relations with true coal-strata.

Considering the enormous development of trap covering some 200,000 square miles in the Deccan,—the granitic basis of the whole peninsula of India,—the area occupied by laterite,—the want of sedimentary rocks, and the hitherto total absence of organic marine fossils in the Deccan (for a few shells brought to notice by the late Dr. Malcolmson were either fluviatile or lacustrine),—the discovery of fossil fish on the margin of the trap region was a novelty necessarily of great interest, as indicative of the former submerged state of the peninsula of India. The fossils arrived in October last, and a glance showed that the remains were imbedded in bituminous schist. The specimens were met with, General Fraser mentioned, near to the confluence of Wurda and Godavery rivers, north of Hyderabad, and south of Nagpur. But as the Wurda runs into the Wein Gunga, and the latter runs into the Godavery, General Fraser probably meant the confluence of the Godavery and the Wein Gunga. The junction of the Wurda and Wein Gunga is about 170 miles north-easterly from Hyderabad, in latitude 19° 87′ N. and longitude 79° 50′ E, and the junction of the Wein Gunga and Godavery is about 115 miles north-easterly from Hyderabad, in latitude 18° 49′ 30″ N., and longitude 79° 56′ 30″ E. I have reason to believe these localities to be from 1,200 to 1,400 feet above the sea level.

The Curator of the Geological Society inspected the specimens of fossil fish, and he considered that they belong to a genus which in European latitudes is usually associated with the Oolitic formation. The Oolitic rock nearest to the locality of these fossils is in Cutch, fully 1,000 miles distant, and with a thickness of from 4,000 to 5,000 feet of trap intervening for a couple of hundred miles; nevertheless, many of the European associates of Oolite exist upon the Wurda and Godavery, namely, bituminous shale, wood-opal, calcareous spar, rhomboidal quartz, agates, chalcedony, hornstone, &c., and the rock itself may be overlaid by the prodigious flow of trap. It was not until the arrival in town recently of my friend Sir Philip Egerton, whose acumen and critical knowledge of fossil ichthyology render his opinion so valuable, that I was enabled to get the specimens examined with deliberate attention. But Sir Philip, with that readiness which makes him at all times anxious to render his knowledge available to others, instantly responded to my appeal, and I am permitted by him to make use, in his own words, of the conclusion at which he arrived after an examination of the fossils. He says :—

"The specimens, with one exception, are much broken, and the ma-

terials scattered confusedly over the schist; but there is sufficient evidence to show that they are all referable to the genus *Lepidotus*, and, most probably, all to one and the same species, *that being a new one.* It is remarkable for the slender proportions of the anterior part of the trunk, and the thickness of the posterior part between the anal fin and the tail. The scales are perfectly smooth, and the free posterior margins entire, without any trace of serration. A ramus of the lower jaw is seen on one specimen, showing the teeth to be conical, with rather elongated basis. There is little doubt but that it is a true Oolitic form, and apparently of the date of the Lias. The schist in which the fish are imbedded reminds me strongly of the bituminous shales of the Lias of Seefeld in the Tyrol. It is very desirable that more perfect specimens should be obtained, since the only one showing the form of the fish wants the head, and exhibits only the under surface of the scales."

In a second note Sir Philip adds:—"The genus Lepidotus extends from the Lias to the Chalk, both inclusive; but your species bears evidence of being one of the earlier members of the race. It was probably an estuary or in-shore fish, from its frequent association with terrestrial vegetable remains, as in the Hyderabad specimens."

Sir Philip Egerton has so ably and completely exhausted the subject as far as the specimens permitted, that it only remains to me to name the new fish; and, as it was very much my practice in my Natural History investigations to associate new species with the localities or provinces where they were met with, I would propose to call the specimen *Lepidotus Deccanensis.*

I have written to India for more specimens, but as the discoverer, Dr. Walker, has lately unhappily lost his life by a fall from his horse, I am not very sanguine about their receipt.

On the Geology of the Neighbourhood of Kotah, Deccan. By Dr. Thomas L. Bell. Communicated by Colonel Sykes, F.G.S.*

[Read April 7, 1852.]

The village of Kotah† is situated on a plain, on the left bank of the Pranhectah River, twelve miles above its junction with the Godavery, in latitude 18° 51′ N., and longitude 80° 2′ E.

* Reprinted from the Quarterly Journal of the Geological Society, vol. viii. part 1, p. 230.—Ed.

† The town of Kotah [or Kotá], on the Chumbul River, is situated about 450 geographical miles to the NNW.

This is the locality selected by the late Dr. Walker for the experiment of boring for coal, and from whence the specimens of fossil fish (*Lepidotus Deccanensis*) were obtained that were figured and described in Quarterly Journal Geological Society, vol. vii. p. 272, Pl. XV. [this vol. p. 301. Ed.] The "Station" where the bore was made is situated on the bank of the river, about half a mile to the NNW. of the village.

To the westward the country (after crossing the river) is slightly undulating, as far as the town of Chinnoor, distant twenty miles; to the east the plain is bounded by an abrupt ridge of hills, distant five miles, which also, in consequence of their north-west and south-east direction, bound the plain to the north; on the south the country is open and flat.

On examining the surface, proceeding from Chinnoor towards Kotah, which lies nearly due east, the road is observed to pass over sandstone for four miles, which, about half a mile from the river Godavery, ceases, and changes to the "black regar" or "cotton soil"; * this continues for about three miles, and disappears as the road leaves the river, the sandstone again becoming visible, which is continued without interruption until we approach the Pranheetah at Annawarrum, distant one mile from it, where the "black regar" alluvium is again entered upon, and ends by forming the nearly perpendicular right bank of the river. The bed of the river measured 666 yards in breadth, with a bottom of fine white quartzose sand; the breadth of stream varies with the season,—at present (June 17) it is narrower than at any other period of the year, and measures only 50 yards, with an average depth of 3 feet. Pursuing this superficial examination in the same line, the "black regar" is found to form the left bank, which is 43 feet in height, and then to pass easterly for nearly a mile, when it is gradually lost, its place being supplied by sand, pebbles, and quartzose conglomerate, the *débris* of the adjacent hills.

The hill which limits the plain to the east is one of the chain extending from Budrachellum; it has a NW. and SE. direction, and is 478 feet high above the level of the plain; its top is flat, and covered with fragments of quartz-conglomerate (with a ferruginous cement) and iron-ore of various degrees of richness, from the yellowish-brown spheroidal masses of clay-iron-stone containing 35 per cent. of iron, to the red oxide containing upwards of 70 per cent. The sides and base are likewise covered with the same.

The hill is composed of unstratified red sandstone, which at places becomes ferruginous, the oxide of iron forming layers from 2 to 4 inches

* A black alluvial earth, supposed to result from the decomposition of trap.

thick: where this occurs the rock is less susceptible of atmospheric influence, and is not worn to the same extent as the surface generally, and the frequent projecting of these indurated portions gives it the appearance of being intersected by a number of septa.

Commencing from the most northerly point to which my observations have extended (Chicala, at a distance of twelve miles from Kotah), and proceeding southerly by the left bank of the river, three ridges of hills present themselves of the same lithological characters as the one already described. These ridges are separated from each other by plains of the "black regar" alluvium. They have a NW. and SE. direction, are flat at the top, and terminate their northerly course at the river in escarpments of various heights. On approaching the "Station," and 200 yards from it, we come upon another sandstone rock of a very different character, inasmuch as we find distinct marks of stratification and no septa of iron-ore. The rock is 36 feet high, and ascends perpendicularly from the water (which is here 14 feet deep); its strike is ENE. with a dip of 10° to the NNW., its surface is bare only to a small extent, being for the most part covered with alluvium of "black regar," which is level with its highest point. The strata of this rock are made up of a number of thin layers arranged diagonally, separated from each other by coloured lines; these thin layers are composed of round grains of white quartz: between the strata is found a layer of conglomerate of quartz-pebbles. A few yards lower down the river the outcropping of laminated sandstone, alternating with clay, is observed, with a similar strike and dip as the rock above; between these outcroppings and the position of the bore-hole the surface is covered with a tough black mud. Proceeding south of the "Station," and a hundred yards from the bore-hole, is a confused heap of argillaceous limestone, extending down the bank of the river for 150 yards; the layers of this rock vary in thickness from one-eighth of an inch to a foot, and are frequently separated from each other by seams of fibrous carbonate of lime; the thickest masses of this rock (weathered) exhibit crack-casts. Two miles lower down the river the sandstone is again visible, presenting the same stratified character as the rock situated 200 yards north of the "Station." The sandstone in this direction extends to Bagartepett, fifty miles on the road to Warungul, but is not stratified.

At the "Station" the boring carried on in search for coal exhibited the following results. The alluvium is 59 feet deep at the bank of the river, but it gradually diminishes in depth, and is altogether lost a mile from the river. Beneath this is a layer of blue clay, 1 foot thick. This is succeeded by a bed of argillaceous limestone: this is seen to outcrop in the bed of a nulla about a mile from the river in a SW. direction; it is 9 feet 1 inch in thickness, and is occasionally fibrous. Under this is

a very thin layer of bituminous shale,* which burns with a yellow flame, emitting a strong odour, and leaving a large residue of white ashes: the thickness of this bed is about three quarters of an inch. It is superimposed upon a second stratum of limestone, 1 foot thick. Below this we have another layer of shale 4 inches deep, followed by a layer of impure limestone and blue clay-rock 8 inches thick, and a bed of bituminous shale 2 feet 1 inch. Then a recurrence of impure limestone 1 foot 9 inches, resting upon sandstone and blue clay 8¾ inches in depth; these cover another layer of bituminous shale, 1 foot 1 inch thick, which is separated from another layer, 1 foot 3½ inches thick, by 1 inch of fibrous carbonate of lime. Limestone, 5 feet 3¼ inches thick, was next cut through, and found to rest upon black sandy clay 3 feet in thickness, 6 inches of which were pierced previous to suspending the work, so that we have the following deposits succeeding each other from above downwards:—

	Ft.	In.
Alluvium of "black regar" ("cotton soil")	15	6
Blue clay	1	0
Argillaceous limestone	9	1
Bituminous shale	0	0¾
Argillaceous limestone	1	0
Bituminous shale	0	4
Fibrous carbonate of lime, impure limestone, and blue clay-rock	0	8
Bituminous shale	2	1
Impure limestone	1	9
Laminated sandstone, blue clay, and shale	8	0¾
Bituminous shale	1	6
Fibrous carbonate of lime	0	1
Bituminous shale	1	3½
Impure limestone	5	3¼
Black clay, containing sand	3	6
	43	11¼

There appears to be no decided evidence of the existence of a coal deposit at this spot, the fossils being so very scarce. The vegetable impressions on the shale are too obscure for determination, and it is to be regretted that the fossils are so few and imperfect. There is only one spot from whence they can be obtained, and almost every stone had been examined before my arrival; such, however, as were collected accompany this memoir.†

* One specimen of black shale forwarded by Dr. Bell, and marked as belonging to this seam, bears fish-remains.

† The specimens of shale here referred to accompany the series of specimens illustrative of the "Section" and of the rocks in the neighbourhood of Kotah. They contain fragmentary remains of the *Lepidotus Deccanensis*, and amongst them are fragments exhibiting parts of the head and tail of that fish. Unfortunately, however, the indications are too obscure for the purposes of illustration.

A water-worn fragment of rock accompanying this communication, but not referred to in Dr. Bell's list of specimens, presented evidence of its containing Crocodilian remains. These have been carefully exposed by the chisel, under Colonel Sykes's superintendence, and the specimen has been examined by Professor Bell and Professor Owen, the latter of whom has kindly furnished the accompanying note.

Note on the Crocodilian Remains accompanying Dr. T. L. Bell's Paper on Kotah. By Professor Owen, F.R.S., G.S.

The Crocodilian fossil consists of a mass of dermal scutes, with a femur and some fragments of other bones, firmly cemented together by the matrix. The scutes are for the most part quadrate,—some square, others oblong; they have numerous well-defined and rather small hemispherical pits upon their outer surface, which is flat and without any carinal elevation. In this respect they differ from the dermal scutes of the existing Gavial, in which the pits are relatively larger, more frequently confluent, and the middle of the pitted surface is in most of the scutes raised into a keel.

The characters of the scutes, as well as the length and slenderness of the femur, in the fossil, agree more with those of the *Teleosaurus* and Amphicœlian Crocodiles than with the existing Gavials.

Notes, principally Geological, on the Tract between Bellary and Bijapore. By Captain Newbold, F.R.S. &c. Madras Army.

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The Notes, of which the following paper is an abstract, were taken during a survey ordered by Government of that line of Post Road, connecting Bombay and Madras, which lies between Bellary and the ancient Mahomedan capital, Bijapore. They commence from Bellary, comprising a line of 164 miles, extending in a north-westerly direction through part of the Ceded Districts, the Nizam's dominions, and the Southern Muratha Country, crossing at right angles the courses of the Tumbuddra and Kistnah rivers as they hasten across the Peninsula from west to east, to add their tribute to the Indian Ocean. The route chiefly lay over a vast undulating plain, constituting a considerable portion of the great plateau that is elevated on the shoulders of the Eastern and Western Ghàts, and intersected by a few subordinate spurs, running nearly at right angles with the great lines of dislocation.

From Bellary to Courtney, a distance of eleven miles, extends a plain based on granite and gneiss, penetrated by numerous greenstone dikes. From Courtney to Yailbenchi, four miles, the plain continues, as before, covered with a superstratum of *regur*, or the black cotton soil of India, to a depth of from 1 to 18 feet, in many places resting immediately on the gneiss and granite; in others on an intervening bed of a calcareous deposit, somewhat resembling the travertin of Italy, though more nodular, and called by the natives *kanker*. It is burnt by them for lime. Like rows of flints in chalk, it is seen also in the lower layers of the *regur*, often with sharp projecting spiculæ of carbonate of lime, which would have been broken off had the nodules been drift pebbles. Here and there, on the surface, and partly imbedded in the soil, greenstone occurs *en boules*, indicative generally of a subjacent dike. Angular fragments of both yellowish and reddish quartz in many places literally strew the surface of the ground, which, close to Yailbenchi, changes to a red clayey soil; and on examination proved to be the result of the disintegration of a bed of micaceous hornblende schist, with gneiss here rising to the surface. Granite greenstone, and a rock composed principally of a reddish foliated felspar, pierced by veins of the same mineral in a more compact form, and tinged of a delicate

green by actinolite, are seen in the walls of the small fort here. The produce of the soil is principally cotton, and juari (*Holcus sorghum*).

From Yailbenchi to Devasamudrum, the *regur* continues covering the surface of the plain, mingled, in greater or less proportion, with the angular *débris* of the subjacent rocks just alluded to; except near the village of Soganhully, where it is interrupted by a bed of a rich red alluvial soil, deposited apparently in this low situation by a number of rivulets flowing easterly from the great tank, or artificial lake of Daroji. This rich soil, deriving additional fertility from the water to which it owes its locality, produces rice and wheat, in addition to other grain; and also sugar-cane. In some places, however, it is impregnated with muriate of soda. A few native salt manufactories, indicated by small mounds on the banks of the rivulets, are visible on the left of the road.

From Devasamudrum, gneiss, with its associated schists, mica, hornblende, and chlorite, constitutes the prevailing rock to the bed of the Tumbuddra. Veins of quartz and felspar cross it in various directions, in which thin seams of an actinolitic felspar, of a lively green, not unfrequently occur. Near Hulhully, on the south bank of the river, a few dikes of greenstone and basaltic trap, containing augite, cut the gneiss in an easterly direction. Calcareous deposits, in the form of a nodular *kanker*, are seen in the rivulets running down the slopes of the plain to the river bed. The soil is *regur*, lying upon the gravelly detritus of the subjacent gneiss, &c., with here and there a thin stratum of *kanker* interposed. The cultivated vegetable products the same as before. The plants, growing wild on the plain, are principally the *Cassia auriculata*, *Mimosas*, *Asclepias gigantea*, and the *Jatropha glandulifera*. The lastnamed plant is almost confined to the black soil. The banks of the Tumbuddra at this point are formed by an accumulation of silt, clay, and sand, brought down by the freshes. The bed is covered with a fine red quartzy sand.

The Tumbuddra is crossed by basket boats to Mustoor, the first village in the Nizam's dominions. The plain rises gently as the traveller proceeds northwards to Umaluti, a walled village about twenty-four and a half miles from Mustoor. Between this place and Tawurghirry, its surface is broken by the protrusion of a bed of milky quartz, rising into a broken ridge of small hills; from which a gradual but stony descent leads to the decayed town and fort of Tawurghirry. Springs of fine water abound, and, with numerous rivulets, maintain an almost unfailing supply of water. The latter feed the Tumbuddra, the bed of which constitutes the drainage line in this part of the Nizam's territories. Judging from the quantity of *kanker* found on the banks of these tributaries, a large proportion of lime must be conveyed by their means to the Tumbuddra, and thence to the ocean. The *regur* continues

to cover the surface of the plain, with but few breaks, from the Tumbuddra to Umaluti, a distance of upwards of twenty-four and a half miles, though not perhaps to the depth seen in many parts of the Ceded Districts. This circumstance might probably be accounted for by the slopes here having a greater angle of inclination, rendering the superincumbent soil more liable to the denuding effects of floods, streams, and the heavy monsoon rains. The *regur* thus becomes blended with the alluvium washed down, and is seen as a stiff greyish mixed clay. Both the alluvial red soil and *regur* are impregnated with muriate of soda and natron. Salt manufactories are seen scattered over the country on the banks of the rivulets. Beyond Umaluti to Tawurghirry, the soil consists of the *débris* of granitic rocks; and is sandy, gravelly, or stony, according to situation and state of disintegration. Near the bed of the Tumbuddra, I have before remarked that the subjacent rock is gneiss and its associated schists. Quitting the bed, these rocks are less seen, while granite and greenstone constitute the prevailing rocks from Chuloor to Umaluti; the former occurs in bosses, knolls, and detached hills, with tors and logging stones, the latter in dikes and loose *boules*. From Umaluti to Tawurghirry, the granite rises in a more decided manner from the surface, taking a south-easterly direction. One of the most considerable of these elevations is a range of hills a little south of the Tawurghirry road, called the "*Caradi Guddi*," from being infested by a number of bears, which are attracted to this neighbourhood by the fruit of the dwarf date that luxuriates in the low moist valley. A bed of white and red quartz assumes the form of a low ridge, covered with jungle, and over which the road passes, called by natives, from its white appearance, "*Pilla Guddi*"; and running SSE. Some of the quartz veins intersecting the granite pass into hornstone with a splintery fracture. The granite is crystalline and contains dark mica in scales, hornblende in small crystals, foliated reddish felspar, and greyish quartz in minute angular fragments. Hematitic iron ore exists largely near the bed of quartz; the slope of the ridge towards Umaluti is strewn with the slag and scoriæ of the furnaces formerly used for smelting it. The Hindus, I am informed, gave them up many years ago, owing to the exactions of their Mahomedan rulers. The agricultural produce of the soil is chiefly juari, cotton, and a little wheat; being at a distance from the river, it is indifferently watered, depending on the dews, springs, and the periodical rains. The majority of the springs about Tawurghirry are brackish; the formation granite, with reddish felspar, in clustered blocks, generally not rising above 20 or 30 feet from the surface. The soil around the town is reddish, arising from alluvium brought down the slopes of the ridge, and the disintegration of the granite rocks in the vicinity. It produces good crops of juari.

A little more than a mile NW. from Tawurghirry, chlorite slate occurs in the bed of a rivulet in nearly vertical laminæ, interseamed with a reddish subcrystalline felspar, having a general direction of E. 10° S. though contorted and waving at various points; the general dip is to the N. About two miles further on a trap-dike intersects the schistose beds, running nearly east and west, and decomposes into a reddish brown soil. Three miles further, near Idlapur, the chlorite, mica, and micaceous hornblende schists appear in the form of low hills, having an irregular direction, but which approaches that of the laminæ of the schists themselves. The chlorite schist predominates, and, losing its chlorite, passes into both a ferruginous and a soft purplish shale, or slate clay, containing much felspar in a decomposing state. The summits of two or three of these hills were crested with a jaspery clay ironstone with cherty quartz in parallel laminæ. A smoke-coloured vesicular quartz is found veining the chloritic slate, and a reddish tough subcrystalline *kanker* is seen in the hollows and sides of the hills. Large masses occur in the roadside, imbedding small nodules of hematitic iron ore, which is profusely scattered in the bed of the rivulets. At Sassenhal, in the bed of a nulla, I found an angular block of a compact rock of a light ochreous yellow colour, having cavities lined with minute yellowish pyramidal quartz crystals. Passing still north-westerly from Idlapur, the hills subside into long wavy swells to Moodianur. The chlorite slate is seen penetrated by a rock of reddish felspar and quartz, in which chlorite is scattered in thin lamellæ, which passes into eurite imbedding minute green crystals of tourmaline. Actinolite occurs in thin veins with quartz, and imparts a fibrous and radiated character to the rock. The direction of the laminæ of the chlorite slate was found to be N. 55° W.; dip 58½°, S. 45° W.; general direction of joints N. 10° E; dip 85°, E. 10° S. The larger beds of quartz conform in direction and dip to the laminæ or strike.

About half a mile beyond Moodianur, the left bank of the Ramtar river, running towards the Kistnah, presents a small section of the rock composing the hill, the base of which it washes. It proved to be quartz rock, irregularly tinged with oxide of iron in almost tabular masses, separated by fissures, having the appearance of stratification, dipping to the NE. at an angle of 13°. As I could discover no interstratified bed of any other rock, I hesitate to pronounce these the lines of stratification. Globular masses of a porphyritic greenstone imbedding reddish crystals of felspar occur on the surface. This bed of quartz rock lies between the chloritic schist and felspathic gneiss, the latter of which is observed about a mile further on, with a similar direction and dip as the former. Veins and beds of a jaspery clay iron ore, with calcareous incrustations, occur in parallel laminæ to the gneiss, which extends into the Southern Muratha Country to Cundigul.

Near Cundigul the chloritic slate again rises to the surface as a cluster of hills, having the same smooth contour as those of Idlapur, and crested with a similar jaspery rock. *Kanker* and calcareous spar occur in the seams; and the surface is strewn with nodular hematite. Many of the specimens of the slate effervesced with dilute muriatic acid, impregnated with lime, probably from infiltration of water, charged with this mineral. The dip is to the N. 45° E. at an angle of 70°, the strike N. 45° W. Passing over the plain at the foot of these hills about a quarter of a mile from the village of Cundigul, a dike of basaltic greenstone, running E. and W., is traversed. The green chloritic slate in its vicinity acquires a dull blue hue; becomes hard and compact, and splits into prisms having smooth planes. The contortions of the strata observed at some distance from the dike may be, perhaps, attributed to the intrusion of this rock. Gneiss is again seen in the beds of the Nundawarghi nullas, alternating with mica, hornblende, and chlorite schist. It is red, felspathic, and contains veins of quartz, felspar, and actinolite. The last mineral often occurs in the seams with a compact siliceous felspar, having a lively green colour, sometimes in drusy crystals, and lining the interior of vesicular cavities. A dike of basaltic trap crosses the plain in a west by northerly direction. At the village of Nundawarghi, I remarked a number of millstones composed of a fine white and red granular sandstone, the grains of quartz cemented together by a felspathic paste imbedding angular and rolled bits of a dark flinty slate, derived from the slate associated with the gneiss, and of a ferruginous rock. These stones I was informed were quarried at Badami and Jalihal, the price from half to one rupee each. The red felspathic gneiss and associated crystalline schists are seen at intervals as far as Cumblihal, where I encamped in the plain. Here the gneiss becomes granitoidal, the red felspar still continuing six furlongs beyond Cumblihal; at the Muddi nulla it is seen alternating with micaceous schist. Dip 60°, E. 20° N. Nodular *kanker* of a faint red, and hematitic iron ore, strew the beds of the rivulets. Near Caradi, the granite loses much of its mica, consisting almost wholly of red felspar and greyish quartz, and assumes the character of a pegmatite and graphic granite. The green actinolitic felspar continues to intersect the rock in thin seams. At Coujaganur the Kistnah river is first seen; thence to Danoor, the tappal village near the ferry, the route lies along its right bank, to which the plain declines with a gentle slope, that increases, however, near the river bed. Numerous streams cut the bank in their progress to the Kistnah, leaving intervening swells of ground, and rendering the road, which crosses them at right angles, uneven and difficult to traverse during the rains, when this tract is partially inundated by the river. In consequence of the thick superstratum

of mixed alluvial and *regur* soil, few opportunites occurred of observing the subjacent rocks. Gneiss, however, was the one most frequently met with.

On the ascent of a low hill a little beyond the small fort of Havcrighi, a dike of basaltic greenstone cuts the gneiss, running nearly due east and west, and slightly distorting the laminæ of the latter rock. Several ramifications are thrown off, one of which has a south-westerly direction. The trap here may be remarked splitting into prismatic fragments with smooth planes. The natives take advantage of this circumstance, and employ the stones thus ready formed in building.

In the bed of the river lie nodules of a reddish-brown and white cornelian, chert, jasper, calcedony, cacholong, semiopal with linear curved and angular declinations, and mocha stones. The pellucid pebbles are sometimes surrounded with an opaque *enduit* which adheres to the tongue, mealy externally, but hardening as it approaches the nucleus. The fracture of the inner part is semiconchoidal, hardness from six to seven of Mohs' scale. Fragments of a dark-coloured basaltic rock still adhere to these pebbles, which, together with their water-worn rolled exterior, indicate them to have been transported from the trap amygdaloids to the west. The swollen state of the river prevented any observation which the section of its bank might have afforded. The sides of the ravines, however, presented gneiss, with both white and red felspar interstratified with micaceous hornblende schists. The latter has a fine and almost slaty structure, brilliant lustre, is easily worked, and split by the natives into long slabs for the purposes of building. Iron pyrites are disseminated. A trap dike running to the east is crossed a little beyond Muddur. The strike of the gneiss, &c., though contorted in some places, runs E. 30° S., and dips at an angle of 60° to N. 35° E. The surface of the left bank is much the same as that of the right; it is covered with pebbles brought down by the river; among them I observed a water-worn bit of a grey limestone, probably brought down by the Kistnah from the plain at the base of the Western Ghàts.

It may be remarked, *passim*, that the Kistnah is one of the most considerable rivers of India. It rises among the Mahavaleshwar Hills, near the western coast, a little to the SW. of Sattara, and, after crossing the peninsula in an east by southerly direction, falls into the Bay of Bengal at Sippelar Point, a little to the S. of Masulipatam. During a course of about 700 miles it receives the waters of the Yairli, the Warda, the Gutpurba, the Malpurba, the Bima, the Tumbuddra, and the Hyderabad or Mussy rivers. Its breadth from bank to bank at Danoor, previous to its junction with the three last streams, as taken by trigonometrical measurement by my friend Lieutenant Kinkead of the Artillery, and myself, was found to be 1,918 feet. The current was running rapidly, carrying the round

wicker basket boats in which we crossed a considerable distance down the stream, in spite of all the efforts of the boatmen.

Accumulations of mud, silt, and sand are daily progressing on the banks, entombing the remains of alligators, fish, and fluviatile shells. This river is thought to be richer in gems than any other stream in India. As it flows through the Palnad Circar, diamonds, cat's eyes, onyxes, and calcedonies occur in its alluvium; also a small portion of gold dust at Paugtoor, in the Nizam's dominions. Near the frontier of the Ceded Districts, beautiful agates are found. Not far from its mouth are some of the diamond mines for which Golconda is celebrated, and at Paugtoor it abounds with amethystine quartz.

After leaving the bed of the Kistnah, the plain rises gradually to the north. On the slope lie some scattered blocks of a fine-grained granite, composed of crystals of reddish felspar, quartz, and a black glittering mica in minute plates. The superstratum of soil beyond the alluvium of the river is red and quartzose. Passing in a west by northerly direction, we reach a long low descent, which slopes gently to the west, to the bed of the Hirri, one of the tributaries to the Kistnah; from this the ground again rises with an almost imperceptible ascent to the west, forming a shallow valley running almost due north. The Hirri river follows its course from Bagwari, flowing southerly to the Kistnah, into which it debouches a little above its junction at Capila Sungum, with the Malpurba. It forms the principal line of drainage of an extensive and fertile tract. Our route lay on the left bank of the stream. In the lower, or more southerly part of the valley, a felspathic zone, extending in an easterly direction and several miles broad, is crossed. This rock varies in lithological character, in some places assuming the form of a pegmatite, at others that of a protogine, being combined with quartz and chlorite. A few loose and imbedded blocks of a granite, similar to that found on the north bank of the Kistnah, occur, rarely without rising to any considerable height above the surface. The felspathic rock, observed in sections presented by the deep nullas running down the slope of the plain, has a pseudo-stratiform appearance, arising from nearly horizontal joints, which might be mistaken for the lines of stratification. It continues as the surface rock as far as the village of Gurdinny, near which it is overlaid by beds of a friable trap, approaching wacké, with an obscurely schistose structure, and penetrated by veins of an earthy carbonate of lime, calc spar, and quartz in crystals. It rises near the village into a small knoll, down whose declivity runs a rivulet, in the bed of which the first section of the great overlying trap formation of the Deccan met my eye. Depositions of *kanker* both in beds on the surface, and veins penetrating the fissures in both rocks, occur in abundance; it is found in a pulverulent and concrete state;

the nodules are not so crystalline as those that are seen in the vicinity of the older trap dikes, which penetrate the granite and gneiss of the Carnatic, the Ceded Districts, and Mysore.

About two miles to the north, on the rising ground on which stands the little fort of Beylhal, the road is literally paved with the *boules* of trap, which, exfoliating in concentric lamellæ, leave circular and oval nuclei; the latter, in their turn, however hard and compact, evince a tendency to a similar process of disintegration. This gives a singular appearance to the surface of the road where the rock is uncovered by dust, presenting a surface paved, as it were, with mere pebbles of compact basalt set in concentric rings of wacké. The nuclei remain prominent from their superior hardness. Calc spar of various shades of white, green, and pink, calcedony in perforated nodules, and in geodes exhibiting concentric annular delineations, and lined with minute crystals of quartz, semi-opal, and jasper, occur in veins imbedded in wacké.

At Umblanur, a walled village in the jaghir of the Muratha chief, Punt Pritti Niddhi, about three miles north from Beylhal, I found the nuclei to consist of a hypersthenic felspar, imbedding crystals of augite; fracture small-grained, uneven; streak, greyish-white. Bits of a dark flesh-coloured eurite, and a porphyritic rock composed of crystals of dark dull green hornblende, imbedded in a paste of a faint bluish-green felspar, exceedingly tough under the hammer, occur in the plain. I searched, but in vain, for these rocks *in situ;* although, judging from the sharp angles of some of the fragments, their proper locality cannot be far distant.

From Umblanur, still proceeding northerly, to within three furlongs from the town of Bagwari, the route continues along the left bank of the Hirri. The trap is observed in the nulla beds to undergo many changes in texture and colour, even in the space of a few yards, from a compact heavy basalt to a friable wacké; from globular to schistose; from black to red and a light brownish-speckled grey. The laminæ of the schistose variety are often intersected by transverse fissures, which divide the rock into rectangular and rhomboidal prisms, similar to those observed in clay-slate near the line of contact with a basaltic dike. These again, by the agency of the mysterious law of crystallisation, which is manifested in a greater or less degree, in both ancient and modern trappean rocks, from the microscopic atoms of augite and hornblende to the prodigious pillars of Staffa and the Giant's Causeway, often assume a pentagonal and hexagonal shape by exfoliation. By process of further exfoliation the angles are worn away, and the prisms assume a globular appearance, which has led some observers to imagine them to have been erratic boulders subjected to the rolling action of water, or, from their abundance and the augite often found in them, to have been showered down on the surface by volcanic agency

Near Bagwari, the beds of the streams abound with *kanker*, indurated ferruginous clay, fragments of red and yellow jasper, trap, amygdaloid, and a few nodules of calcedony ; the concave surface of the botryoidal varieties of this mineral not unfrequntly exhibit a succession of pentagons and hexagons.

From Bagwari to Mangoli, the route lies over plains, the lowest stratum of which, as seen in wells to the depth of 20 to 50 feet below the surface, and beds of nullas, is the overlying trap. About two miles NW. from the former place, it is overlaid by a sheet of a conglomerate composed of a nodular and pisiform iron ore, and fragments of ferruginous clay imbedded in a travertine-like paste of carbonate of lime, coloured of a light ochre-brown by oxide of iron. The bed of a nulla presented the only section (of this stratum) ; it was here four feet thick, covered by a layer of black cotton soil or *regur*, and resting immediately on the concentric exfoliating trap, which was penetrated by seams of a whiter and more earthy carbonate of lime, as shown in the right hand corner of the plan.

Large masses of a lateritic rock, cemented together by calcareous and ferruginous matter, and having a smooth shining *enduit*, which imparts a glazed appearance to the surface, occur in the calcareous conglomerate. The extent of the latter, owing to the thickly covered nature of the soil, I was unable to trace ; but it is met with at various places between Bagwari and Mangoli, and most probably continues almost uninterruptedly, overlying the trap for the greater part of the distance ; viz. twelve and a half miles. Near Mangoli, the trap again appears as the surface rock, seamed however, and almost broken up, by the immense quantity of calcareous matter penetrating between the laminæ. The lime is seen to take up some of the colouring matter of the augite or hornblende of the trap, and is stained of a mottled green and brown. The trap exhibits superficial dendritic appearances, generally dark brown, with yellow or brownish ground on the smooth surface, into which it readily divides on being struck with the hammer. This facility of division arises from natural microscopic fissures pre-existing in the substance of the rock, sometimes visible to the naked eye. The fragments are of different shapes, but almost invariably angular and frequently prismatic. The trap varies from a compact black and phonolitic basalt, to a loose light grey wacké, specked with minute ferruginous spots, and still preserves both the laminar and globular forms described above. Veins of a reddish colour, without any definite direction, are observed intersecting it. Their composition does not appear to vary much from the dull brown grey rock that forms the prevailing colour of the trap in this vicinity, except in being more ferruginous. Deep and nearly vertical fissures, dipping generally to the W. 70° S., cleave its

tables in a direction N. 25° W. A number of small vesicular cavities pervade its structure, the axis of whose longest diameter is generally N. and S. may be received as indications of the course here taken by this great *coulée* of trap.

Notes, principally Geological, from Bijapore to Bellary, viâ Kannighirri. By Captain Newbold, F.R.S., &c. Madras Army.

No. 2.

The city of Bijapore stands on an immense sheet of overlying trap, with an undulating surface, though here and there small step-like descents, characteristic of trappean formations, may be observed; but none of sufficient altitude to disturb, to any great extent, the generally level appearance of the surrounding country. As far as the eye can reach, on the north-west horizon are seen, from some of the higher points of the city, low wall-like ranges of sandstone. The almost unbroken extent of the plain of Bijapore affords but little scope for the geological examination of the strata subjacent; the observer must therefore dive into wells, pass up the beds of rivulets that water the surface, search for quarries, and descend into the fosses that surround fortified places. In failure of all these, the walls of forts and other buildings present a mineralogical collection on the large scale which usually affords a clue to the petrographical nature of the surrounding formations, as natives seldom trouble themselves to bring building stones from any distance, preferring mud if the former material be not at hand. The surface of the plain is, in general, strewed with fragments of trap, amygdaloid, quartz, calcedony, opal, cacholong, calc spar, and zeolites, kanker, nodular iron ore, and a conglomerate of ferruginous clay and iron ore imbedded in compact kanker. These, decomposing together in unequal proportions, form a superstratum of a light brown soil, in which small crystals of a pearly calc spar and zeolite glitter like particles of silvery mica or talc, in soils formed by the decomposition of gneiss and granite. This light brown soil is extremely fertile, producing abundant crops of wheat, chenna, bajra, and juari: it is very different in colour and appearance from the *regur*, which I have seen covering with its black crust, rocks of all formations, at heights above the present drainage level of the surrounding country, the granite and gneiss of Bellary, a small part of Mysore, the limestone and sandstone of Cuddapah, and the slates at the foot of the Nulla Mulla hills. Beneath the soil the trap, in public roads and other places liable to abrasion, is often seen in the state of the concentric

decomposition alluded to in speaking of Beylhal, and also in a schistose form. In deep sections, such as wells and quarries, the rock assumes a tabular appearance, splitting almost horizontally into thick stratiform masses, which are again intersected, at right angles, by almost vertical fissures, imparting a columnar structure. At Turvoi, a village about four and a half miles from the Mecca gate of Bijapore, beyond the ruined palace of Aurungzebe, the basalt rests conformably upon a bed of amygdaloid into which it passes. Large beds of the amygdaloid occur in the trap, rising above its surface, as seen near the Allahpur gate of Bijapore.

The fissures, though nearly vertical, do not appear to indicate any axis of disturbance, dipping irregularly. At the bottom of a well at Tangoli, about fifteen miles south of Bijapore, the direction of the fissures was N. 25° W., dip W. 20° S., joints horizontal. At the quarries of Bijapore, the fissures took a direction N. 20° E., joints dipping 5° to E. 20° S. Calc spar occurs in thin discoloured seams, lining the fissures. A number of empty vesicular cavities pervade the rock, which appear never to have contained any mineral substance, and probably were occasioned by the evolution of gases while the rock was in a liquid state. Their direction is not uniform, but it will be found generally south-westerly, conforming to the axis of the trap's direction.

The petrographical structure varies often in the space of a few feet, from a compact greyish-black basalt, having a granular structure and conchoidal fracture, with streak of ash grey, to a soft wacké speckled with brownish decaying crystals of augite and amphibole. The trap in this vicinity has a blush of red traceable in the darker portions, and becoming stronger in the wacké and amygdaloid ; the latter has for its basis a fine red clay. The dark compact variety melts into a black glass, and is faintly translucent at its edges, exhibiting a dull green; the rest are opaque, and melt with difficulty into a greenish black glass. Some varieties, which appear to contain much siliceous matter, are infusible. The less compact trap has an uneven fracture. When reduced to a coarse powder, a few of the fragments are taken up by the magnet ; the fine powder is of a dull greenish grey. It does not gelatinize when treated with acids. Its specific gravity I found to be 3·35.

The variety used in building the splendid palaces, mosques, and mausoleums of Bijapore is of a deep reddish-brown opaque, and of a granular fracture, approaching earthy. This rich colour adds much to the appearance of the ruins. The rock is by no means uniform in texture, being more or less vesicular, amygdaloidal, or clayey, and subject to exfoliation ; consequently, when the stone has not been carefully selected, it gives way under the superincumbent pressure; many

of the structures are rapidly falling into decay on this account. The variable nature of the trap is, perhaps, most strikingly seen in making the circuit of the city walls, which are built upon the rocks from which their materials have been quarried. Not only is the disintegration seen in the walls themselves, but wherever they rest on an amygdaloidal foundation, which, exfoliating, splitting, and giving way, causes whole masses of masonry to be precipitated piece-meal into the fosse; vertical fissures in the walls commencing at the base, and, proceeding upwards, mark the site of future and extensive ravages. The masonry on the firmer parts of the rock is in excellent preservation; if well selected, it would make a good building stone, and is capable of receiving a fine polish, as shown in the bas relief round the Sijdeh recess in that little gem of Moorish architecture, the Mecca Mosque within the citadel, which is constructed of the more compact variety of the purplish amygdaloid just mentioned.

The basis of the rock is felspar, with amphibole and augite in various proportions. The latter mineral (augite) is not much seen in the red amygdaloid rock. Olivine is of rare occurrence. Vesicles are seen in all varieties, both empty and containing green earth, which becomes brown or black on long exposure, calcedony, cacholong, calc spar, quartz, zeolites chiefly radiated, stilbite, heulandite, and mesotype, when it assumes an amygdaloidal stamp. These minerals also occur in veins, and are most abundant in the red amygdaloid, to which they impart a reticulated or porphyritic appearance, as they chance to occur in veins or crystals. Geodes of calcedony are seen also containing drusy crystals of quartz and of zeolite, enclosing crystals of carbonate of lime. I have seen veins of crystalline quartz splitting in the centre, in a direction parallel to the sides, containing all these minerals on their inner surfaces. Agates are sometimes, but rarely, found imbedded; greyish crystals of glassy felspar are met with in the semi-compact varieties; also small nodules of a compact cream-coloured opaque zeolite with a faint tinge of buff, and marked with concentric annular delineations, resembling in shape those in orbicular granite.*

Marched this morning (July 9th) on the new route to Hukli, a place about twelve miles SE. from Bijapore. The brown soil, arising from the disintegration of the subjacent trap, continued about a mile, when it was succeeded by the *regur*, strewed with abundance of grey kanker in small nodules. At about three miles from Bijapore, the

* Some of these nodules are earthy, and have a powerful argillaceous odour. The most compact have a hardness about seven (Mohs') fracture semi-conchoidal, inclined to splintery —opaque. Before the blow-pipe they intumesce and phosphoresce slightly. They gelatinize when treated with nitric and muriatic acids. Some of them contained acicular, microscopic and minute crystals of a mineral resembling chabasite.

kanker and iron ore conglomerate occur in masses; the latter is used as a revêtement to a small well into which I descended, and found the water percolating through layers of kanker, dark earth, and iron ore; the fissures were nearly vertical; direction N. 5° E. dip. SE. by E. Trap—generally covered by a bed of reddish kanker, on which rests the cotton soil, passing into a reddish amygdaloid, recticular and porphyritic, containing calc spar and zeolites—continues to Hukli. Portions of its red clay basis intumesce, and curl up before the blow-pipe, indicating the existence of numberless minute particles of zeolite disseminated throughout its substance. With muriatic acid, it formed a gelatinous mass; in this respect resembling the Silesian variety of basalt analyzed by M. Lowe of Vienna. Wells of fresh water are of frequent occurrence. The same formation continues to Bagwari. Between Hukli and Bagwari, a branch of the Doni is crossed, having black steep banks of cotton soil; this stream is a treacherous bed of saline and sluggish water, unfit for the use of man or beast. The earth of its banks is highly impregnated with muriate of soda, as shown by the efflorescence on the surface, and by the adjacent salt-works. About seven miles from Hukli, between Musibinahal and Bagwari, I observed a flat-topped hill, about a mile from the left of the road. It was composed from base to summit of a tabular lateritic rock. Cuboidal masses of the same crowned the summit, exactly resembling the masses on the tops of the smooth laterite hills of Malabar and Canara. Further east, about a mile, runs a low ridge of hills with a NE. and SW. direction, the flat contour and waving direction of which powerfully reminded me of the laterite hills on the Western Coast. I examined the end of the range, and found it to be of the lateritic rock just alluded to; the rest also appear to be of the same rock. About twelve miles to the south of these rise two other flat-topped hills at Nagarwar, which, I am assured by the natives, are of the same rock. The small hill of Hori Math, near Ingliswar, celebrated as being the site of the miraculous birth of the founder of the Jungum sect, is entirely composed of the lateritic rock. These lateritic hills are remarkable, as rising above the low trap elevations amid which they are situated, and are the only hills of any height to be seen for miles around. This circumstance, which is not of rare occurrence in other parts of India, is evidently the result of the denudation of the subjacent trap, the beds of laterite being once probably continuous over its surface. The trap is seen in the valleys and nullas at their base, on which the lateritic rock rests in tabular, horizontal masses. A siliceous porphyritic rock, having cavities lined with minute brown crystals, is associated with this rock, and is found in loose blocks on the surface. The imbedding paste is a light-coloured highly indurated jaspideous clay. Before the blowpipe, *per se*, the crystals lose

their colouring matter, but fuse with carbonate of soda into a white enamel.

Went about two and a half miles to the east of Bagwari, to see the quarries whence the compact blackish trap is dug used in building the walls of that town; found the quarry to be nothing more than a large assemblage of basalt *en boules*, lying partly on, and partly imbedded in the soil covering a long swell, probably a basaltic dike, through the surrounding trap. I searched in vain for an excavation affording a section of the intrusion of the former. The basalt is different in mineral structure from that seen passing through the granite, gneiss, and slate of the Ceded Districts, the Nizam's dominions, Mysore, Malabar, and Canara. It is now amygdaloidal and vesicular, and contains small globules of calcareous spar, zeolites, and calcedony. The vesicles, however, are more usually empty: some of them contain a brownish-yellow earth, into which I have observed the zeolite to decay, and also calcareous spar, coloured with the peroxidation of iron, which exists plentifully as the black protoxide and carbonate. The fracture is conchoidal, fragments faintly translucent at the edges; streak greyish-white; melts before the blow-pipe into an intense green glass. It contains little amphibole, and appears to be composed almost entirely of augite and felspar.

The lateritic rock in the vicinity of Hori Math appears, generally, to contain more iron than the rock of Malabar and Canara, and is consequently of greater specific gravity. The specimens I obtained did not contain lithomargic earth, nor so much quartz as the latter; the tubular sinuosities are frequently lined, like those of the Malabar variety, with an ochreous earth arising from the decomposition of quartz and felspar, and tinged of various shades of brown and yellow by the oxide of iron; this earth forms a compact paste, cementing more firmly the component parts of the rock together: it exactly resembles, in this respect, portions of the Malabar laterite. It is not so soft interiorly. This paste adheres to the tongue, and gives out an argillaceous odour when breathed on. The more compact parts of the rock, forming the coating of the tubular cavities, become magnetic before the blow-pipe, and are converted into a dark grey slag.

Proceeding in a SE. direction, by Jawannaghi and Narsinghi, to Aleopa, a village east of Umblanur, the road lies diagonally across the low trap swells which have generally a SW. direction, though their lines sometimes intersect each other at obtuse and acute angles. The tops of the swells are mostly slightly convex, though often terrace-like, and are composed of the more compact and globular trap. In the banks of nullas, the trap and amygdaloid may be observed alternating and passing into each other; when they occur horizontally, the trap is

generally the surface rock; this may be owing to its superior hardness, and capability of withstanding the abrasions caused by the elements. The amygdaloid contains irregular bits of decaying felspar and numberless vesicles, often filled with green earth and crystals of carbonate of lime. The former mineral, in moist situations, assumes a black or deep brown colour in decomposition, giving a speckled appearance to the rock, resembling that of the toadstone of England. Before the blow-pipe these dark spots are converted into black slag. In the bed of a stream, a few hundred yards NW. from the village of Kunkal, I found slender prismatic crystals of carbonate of lime, fasciculated in sheaf-like forms, with dark pieces of chert in a friable mass of the amygdaloid; the radii of the calcareous crystals were three inches in length, and of a faint amethystine hue.

About two miles to the north of this village, indications of a change in the formation were seen in the angular bits of red pegmatitic and quartz rock, that occur on the plain and in the beds of nullas, which become more frequent as the villages of Kunkal and Alcopa are approached. A few hundred yards south of the latter, I found these indications confirmed, and the quartz rock *in situ*, in tabular masses in the bed of a nulla. Alcopa is situated near the south-eastern foot of a slope, on the top of which the trap has the usual compact and globular form, while at the base it is tabular, schistose, and amygdaloidal. A few hundred yards to the south of this village, the trap formation ceases at the foot of a low range of flat-topped hills of sandstone. In the hope of discovering the line of termination, I spent several hours in searching the beds of streams, and visiting the quarries in the neighbourhood, and at last discovered it in the bed of a nulla, about three hundred yards south of the village; here, after clearing away the gravel and detritus composing the bed, I distinctly saw the trap overlying the sandstone, and penetrating some of the numerous fissures that cleave the latter. I had anticipated this fact from the circumstance of the little disturbance in the latter rock, which occurs in tabular horizontal masses, having a rhomboidal shape from being intersected by fissures, with a varied direction, but generally N. 65° W., crossed by others trending S. 20° W. Where the trap had penetrated them, I did not find the two rocks adherent, or passing into each other; but perfectly distinct and separate, and occasionally a thin calcareous seam intervening. Both the trap and sandstone seem to be slightly altered by contact, the former becoming less crystalline and more earthy, but often extremely tough, and splitting into small fragments, with numerous microscopic fissures intersecting its structure. The colour of the sandstone, from a few lines to several inches distant from the contact, is generally reddish, passing into a deep reddish-brown. There was no appearance of semi-

fusion, or intermixture, nor entangled masses of sandstone in the trap, a circumstance coinciding with the observations of Lord Greenock, in his account of the phenomena displayed by the igneous rocks in the neighbourhood of Edinburgh, in their relations to the secondary rocks; nor did I observe any solidification in the former, as noticed by Professor Hausmann, in the sandstone altered by heat near the blast furnaces at the Steinrennerhutte in the Harz; on the contrary, it was of a looser texture than ordinary. In structure, from a loose and variegated grit, it approaches a compact quartz rock, containing disseminated portions of decomposed felspar, which, falling out, leave a number of minute oval cavities. This stone is much used in building by the villagers in preference to the trap. I saw no veins penetrating the sandstone; pegmatite occurs in scattered blocks; the *situs* of this rock cannot be far distant, judging from the sharpness of the angles of these fragments.

Proceeding in an easterly direction towards Talicota, the trap formation extends to the village of Mudkeysur, three coss from Alcopa, when it is succeeded by a bluish-grey compact limestone, which I first observed in the bed of a nulla. No section occurred, showing its contact with the sandstone, the surface of the country being covered with a thick stratum of soil; but from the easterly dip of both rocks, it is evident that the limestone is the uppermost. It continues the surface rock to the most easterly point of my observation, viz. Talicota. In a deep well at Munjghi, a coss west from Talicota, the bed of the Doni river and the plain in front of the Talicota fort gate, it occurs in stratified masses, with a very slight dip, varying according to the rise of the plain. In the well the dip was only 2½° E. 5° S. Dividing the limestone from the surface to the bottom of the well was a fissure, a foot wide, direction S. 5° W., filled with a buff-coloured earthy kanker and angular fragments of the limestone rock. The latter in mineral character resembles the Cuddapah limestone, but is generally lighter in colour, varying from dark blue to pale buff or cream, and has few traces of pyrites. The minerals associated with it are hematite in small nodules, often occurring disseminated like strings of beads through its structure, which, falling out, leave regular lines of small holes that resemble the perforations of boring insects, and the tubular sinuosities in laterite. Angular fragments of a buff-coloured jasper are strewed among those of the limestone, and, from their variolated exterior, appear to have been in contact with basalt, possibly limestone passing into jasper. I have often noticed the Cuddapah limestone passing into chert, from contact with basaltic dikes. The softer and finer varieties of the cream-coloured limestone found in the vicinity of Talicota are well adapted for lithographic purposes. Some of the

specimens which I brought hence were sent down to the lithographic establishment at St. Thomas's Mount, and found to answer.

I observed the limestone to the SW. of Talicota nearly five miles. About two miles further in the same direction, the overlying trap occurs in the bed of a nulla, a little to the E. of the village of Gonahal, and continues for about a mile, when sandstone, in isomorphous masses, forms the surface rock, and is also seen in the bed of a nulla, in which lay angular blocks of both the abovementioned rocks and fragments of the red pegmatitic stone. Trap prevails between Gonahal and Contogi; it is seen a little to the west of the latter village, overlying the sandstone in the bed of a nulla. The latter rock is here observed to separate into contorted laminar flakes, of a reddish hue and friable structure near the line of junction; the former is earthy in texture, as before observed. A few feet from the junction, the sandstone resumes its usual texture and colour. Between the flakes calcareous incrustations have taken place. Between Contogi and Mudibhal, trap and amygdaloid are the surface rocks. Immediately to the west of the latter place rises a low ridge of finely-grained sandstone, where the quarries for millstones, for which Mudibhal has long been known in this quarter, are situated. The rock lies immediately under a stratum of *regur*, in tabular masses, intersected by vertical fissures running E. and W., and crossed by others at right angles; horizontal fissures also occur, dipping at about one and a half to the E.; these afford great facilities to the Wudras in excavating masses for pillars. A sort of pickaxe, wedge, heavy hammers, and levers are the only implements used: blasting is had recourse to, to split the larger blocks into pieces for the millstones. The masses of rocks, though red and variegated near the surface, are generally white and crystalline in the centre, having decaying portions of felspar disseminated. The millstones are shaped on the spot, and exported to the surrounding districts, and to the Nizam's territories. They fetch from four to sixteen annas each; fire is not used to separate the masses, as in granitic rocks.

A little west from the sandstone hills, the red felspar rock, with mica interspersed, occurs in unstratified knolls and masses. This continues to Hallighirry, whence the formation to the Kistnah is gneiss, with a few blocks of the granite protruding. A dike of the crystalline greenstone occurs between Lepghirri and Hallighi, E. and W. direction. The Hindus rarely employ the overlying trap for building, preferring to bring sandstone or granite from a considerable distance. This is shown in the old Hindu temple in Bijapore, and villages in the vicinity of Contogi. East of Mudibhal the Idgah hill affords a good specimen of the globular trap; it resembles the greenstone dikes of the Ceded Districts, at a distance, in colour and contour; but the mineral cha-

racter of the rock differs in containing little hornblende: it is tough, much less crystalline, and contains zeolite and calcedony imbedded in nodules. It decays into a deep red earth.

From Sassenhal and Jumlapur to Nundapur, the road passes over the NW. extremity of the Idlapur schistose elevations, before noticed. From Jumlapur, where the chlorite slate is seen at the usual angle of elevation, the ground rises for about a mile, when a narrow greenstone dike is crossed, running E. 10° S. About 40 yards further, the main dike is traversed, running in an almost similar direction, which covers the summit and descent of the elevation with globular and angular fragments, almost as far as Nundapur, a distance of three miles. At the base of the elevation on which this village is situated, the slate is seen in the bed of the nulla, dipping at an angle of 60° N. 45° E., *i. e.* from the dike. The schists on the western side of the dike, observed yesterday at Sassenhal, dip at an angle of 72° to the SW., *i. e.* from the dike. The greenstone differs not from that usually seen in the Ceded Districts, being crystalline or porphyritic near the centre, imbedding crystals of a greenish felspar, and becoming more compact as it approaches the edges: amphibole and felspar, intimately mixed, are its chief constituents. Near its eastern flank these minerals separate, and it passes into a sienite, which is exceedingly tough under the hammer; the felspar crystals, fast decomposing, form a compact paste. The chlorite slate, in the immediate vicinity of these plutonic rocks, loses its fine slaty character, becomes thick-bedded, compact, and of darker colour, and is penetrated in every direction by contorted quartzose veins, the planes of which seem almost as varions as their flexures. At the distance of a furlong and 100 yards SE. from Nundapur, a red felspathic dike occurs in the gneiss, almost concealed by a superincumbent mass of friable kanker: small crystals of a scaly graphite, with a shining steel-like lustre, occur disseminated in this vein. The gneiss alternates with chloritic slate and beds of a red felspar rock; its laminæ are much contorted, and have here an easterly direction. One mile and a furlong in the same direction from Nundapur, the bed of a stream is crossed, where a dike of a compact reddish felspar rock (Eurite ?) cuts the gneiss in a direction of N. 60° E., flanked by a thick bed of reddish felspathic granite, containing both mica and chlorite in lamellæ, and a little quartz. This rock and the gneiss are much weathered. Six furlongs hence, the gneiss assumes a granitoidal form, appearing in rounded blocks, with concentric exfoliations. Three miles from Nundapur, a trap dike crosses the gneiss, running westerly; and another, at four miles five furlongs, having a similar direction. A furlong from this, a large dike of the red euritic rock, about 200 yards broad, occurs in the same direction, flanked by a bed of the red felspathic rock, large beds of kanker accompanying the intrusion of the dike. I saw an immense bed of this

calcareous rock, lying as a flat table on the gneiss near Manadhal. From this place to Kannaghirry, a distance of eleven miles one furlong, gneiss, granitoidal gneiss, forming gentle elevations, and scattered surface blocks occur; the associated schists of chlorite and mica are less seen. A trap dike occurs at the distance of five miles five furlongs from the former village; direction W. 15° N. In the bed of the stream, forming in part the fosse of the fort of Kannaghirry, gneiss is seen alternating with mica and hornblende schists, both thick-bedded and laminar. On the NE. flank of the fort, a dike of pegmatite, with a close small-grained sub-crystalline structure, is seen passing through the gneiss, and in a direction parallel with that of the laminæ. In the latter rock, a vein (five inches broad) of large crystals of felspar and quartz, running N. 25° E., exhibits a dislocation to the E. of seven inches. A fissure traverses it for some distance longitudinally, running also into the schist. The walls of the fissure are lined by quartz passing into hornstone.

About four miles north by west from this, near the village of Hanumanhal, I saw on the road side a monument of a Hirlu, or a hero slain in battle, evidently of high antiquity. It consisted of a slab of gneiss placed in a slanting position, on the surface of which a male and female figure were rudely sculptured in bas relief; the former was armed, and in the attitude of combat; the latter, with uplifted hands, seemed in the act of throwing herself into his arms for protection. The relations and descendants place flowers and offerings of oil and milk, as offerings to the manes of the brave: the pious passenger deposits a stone, of which a large heap at the foot threatens to overwhelm the monument and the hero altogether. It is probable, many of the tumuli of loose stones observed in many parts of India cover similar antiques.

I shall conclude these notes with a few observations on what I term the great overlying trap formation of Central and Western India, the southern limit of which has been just described, in contra-distinction to the hills and dikes of greenstone associated with the granite, gneiss, and metamorphic schists of Southern India, which I take to be a distinct and more ancient rock.*

The overlying formation has a south-westerly course; its southern margin terminating, according to Mr. Fraser, near Malwan, in latitude 15° 53′ N., and longitude 73° 47′ E., on the Western Coast of the Peninsula, and its northern limit between Bulsar and Gundavie below Surat, between the 20th and 21st degrees of north latitude. Its boundaries

* This opinion is chiefly grounded on the relative position, age of associated rocks, and mineralogical distinctions, which are very striking. The zeolites, calcedonies, green earth, olivine, and calc spars, so abundant in the formation just described, are never or rarely seen in the trap a little to the S. of the Kistnah. The latter is never seen overlying fossiliferous rocks in continuous sheets, but occurs as dikes in granite and the older stratified formations.

at Gundavie, according to Dr. Lush, are strata of clay containing kanker. Proceeding southerly on the sea coast between Bassein and Surat, horizontal strata of sandstone are seen resting upon it, supposed to be identical with the fossiliferous rock of Kattywar, and which may be accounted as the newest sandstone formation of India. Still further south, at Bombay, it is fringed by a recent formation of coral and shells; and N. of Malwan, it meets with the greenstone, granite, and sienite of Southern India. Thus the western extremity of this formation occupies in its breadth an extent of sea coast approaching five degrees of latitude. Proceeding inland in a NE. direction from the vicinity of Malwan, its southern boundary may be described by a line drawn thence through Merritch and Gurdinny, a village about 40 miles SE. from the city of Bijapore to Bider; thence north of Hydrabad to Nagpore; and from Nagpore north-easterly towards Sohagepore and Sagur to the 82nd degree of east longitude, as observed by Franklin and Coulthard. At Gurdinny it rests on granite, a broad pegmatitic zone intervening. A little to the east of Gurdinny, at Mudibhal, on a crystalline sandstone; and at Nagpore on granite. Its north-eastern limit has not been accurately defined; straggling *coulées* of a similar trap (containing olivine, calcedonies, and agates), have, however, been traced by the Rev. Mr. Everest as high as Gwalior, which lies in lat. 26° 15′ N. and long. 78° 1′ E. It is said to extend still farther toward the east up to the Rajmahal Hills, though it would appear that its continuity here becomes broken up. Assuming Gwalior as its north-east corner, we will return towards the western coast by the northern limit, passing from Gwalior in a south-westerly direction to Neemuch; whence, taking a direction more southerly to Dohud, as traced by Captain Dangerfield, it passes by the east of Baroda to the sea near Bulsar, a little to the south of Surat. On this last line the trap was found at Sagur, to rest on shell limestone, and on the limestone, greenstone, quartz, argillaceous, and talcose rocks of Oodipore. At Bulsar, as before stated, it is bounded by strata of clay and kanker.*

Such is the unparalleled extent of this vast sheet of trap, covering a space, with some interruption, of 250,000 square miles.

Since writing the above, I have had the pleasure of perusing Colonel Sykes's admirable paper on this great trappean region, and perceive that he assigns to it an area of from 200,000 to 250,000 square miles only; but adds, however, that it appears to him that the above are not the absolute limits of the trap. My own observations, taken during journeys to Bijapore, Bider, and Culburga, will have served to trace its SW. boundaries more distinctly than has hitherto been done.

* It is probable that the amygdaloidal trap found overlying a bed of limestone, containing oysters, limnæ, small melaniæ, &c. at Peddapungali near Rajahmundry, discovered by Colonel Cullen, is an outlier of the great overlying trap formation.

Sketch of the Geology of the Southern Mahratta Country. By Alexander Turnbull Christie, M.D.

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Geognosy.—The geognostical arrangement of the rocks of the Indian Peninsula is everywhere very simple; and a great uniformity prevails throughout the whole country, from Cape Comorin even as far as the Ganges. The same formation, in many instances, extends uninterruptedly for several hundred miles in the same direction, and consequently that great variety, and those frequent changes within a short distance, which are so conspicuous in Britain, are seldom met with among the rocks of India.

The principal rocks in the peninsula of India are granite, transition rocks, old red sandstone, trap rocks, and, superior to all these, a ferruginous claystone. The Darwar district, and the adjoining coast, contain specimens of all these rocks, and will, therefore, serve as an example of the general geognostical structure of the Peninsula.

Granite.—This appears to be the most abundant rock in the Peninsula of India. It stretches, with few interruptions, from Cape Comorin to beyond Nagpore and Ellichpore, occupying a great part of the Carnatic, Malabar, and Mysore, nearly the whole of the Nizam's dominions, and a large part of Barar.* It is also met with in many places still further north, namely, in Malwa,† Bundelcund,‡ and in the neighbourhood of Delhi; § and Lieutenant Gerard found some of the highest of the Himalaya mountains to be principally composed of it. ||

All the eastern part of the Southern Mahratta Dooab from the Sungum¶ of the Kistnah and Tumboodra, to near the British frontier, consists of granite; but west of that, namely, in the British territory, it only occurs occasionally, protruding in a few spots through the schists, by which it is covered. It also occurs in the southern parts of the district; the Mysore granite extending, in some places, as far as, but seldom much

* I state this principally upon the authority of the late Dr. Voysey, whom I met at Hyderabad, in 1823; and I myself travelled through a great part of the Nizam's dominions.

† Vide Malcolm's Central India, vol. ii. appendix.

‡ Vide Transactions of the Wernerian Society of Edinburgh, vol. iv. p. 26.

§ Vide Transactions of the Geological Society of London, new series, vol. i. pp. 1, 2.

|| Ibid, p. 127, *et seq.*

¶ Sungum signifies the angle of land formed by the junction of two rivers.

beyond, the frontier. But although it be met with in comparatively small quantity in this district, yet, considering its very great importance as conncted with the general geognosy of India, I will not confine myself to the appearances exhibited by the few specimens met with here, but will also avail myself of the observations I have been enabled to make on the granite in other parts of the Peninsula.

The granitic tracts of India exhibit the same general features as granitic countries in other parts of the world. Rugged hills, with bold denticulated outlines, lie heaped together in the greatest irregularity, or occasionally form an obscure ridge, the crest of which, when interposed between the spectator and the evening or morning sun, presents the most fantastic forms. Some of these ridges, when their dark outline is seen at twilight, against a ruddy western sky, emulate, in their varied forms, the capricious shapes of summer clouds; and we can then trace along their summits the appearances of castles, trees, men, and various fantastic groups. Many of the hills have the appearance of collections of large fragments of rock thrown confusedly together by some convulsion of nature; while frequently large masses, piled with great regularity on each other, look like the gigantic remains of Cyclopean architecture. Huge insulated masses, forming considerable hills, in many instances, rise abruptly out of a plain, to a height of several hundred feet, and present nearly perpendicular faces on several of their sides; thus affording situations of immense natural strength, which have almost invariably been taken advantage of by the natives for the erection of forts. These insulated hills are generally met with at the edges of the granite tract, where it is succeeded by the transition rocks; and being situated in the midst of very extensive plains, when they are seen from some distance, they have exactly the appearance of rocky islands in the midst of the ocean.*

The hills have very often a mammillary form; their sides being bare and smooth, and having generally large detached plates resting upon them, which appear as if they would the next moment slide down the smooth surface into the plain below.

The valleys are irregular, are strewed over with fragments and immense rolled masses of granite, and sometimes afford the most picturesque scenery. Notwithstanding the barren nature of granitic soil, the country is, in many places, covered with jungle.

Upon a superficial examination, the granite of India might be pronounced to have several distinct structures, such as the stratified, tabular, columnar, &c., but all of these may (I am convinced, from pretty

* Some of the strongest forts in India are of this description; for instance, Chittledroog, Gooty, Copaldroog, Eidgheer, &c.

extensive observation) be referred to the laminar; the laminæ giving rise, by the infinite variation in their direction, form, thickness, extent, and mode of disintegration, to the different appearances alluded to. The most common variety appears to be the curved laminar; the laminæ varying in their thickness from a few inches to many feet, and almost infinitely in the degree of their curvature. The bare mammillary-shaped hills and knolls, which are so common throughout the granitic tracts of India, owe their origin to the curved laminar structure of the granite. They have almost invariably loose angular plates resting on their sides, which have arisen from the most superficial of the laminæ having split, and separated from those beneath.*

The laminæ are sometimes straight, but seldom to a great extent; for, if traced to a short distance, it will generally be found that they soon lose their straight direction, and become curved. These straight laminæ (as might be expected) vary in their dip, from horizontal to vertical.

The granite, on one side of a small hill at Shawpore near the Beema, has somewhat the appearance, when seen in a certain direction, from a little distance, of being columnar; but when it is examined more closely, it becomes evident that this appearance arises from the following circumstance. The laminæ of the granite, on that side of the hill, are straight and vertical, and had formerly made a very rapid curve at the top. By the influence of the weather, the curve had been worn away, and had thus allowed the inferior vertical parts of the laminæ to separate a little from each other; and, accordingly, when seen transversely, they have somewhat of a columnar appearance.

The laminæ of the granite are very often divided by natural joints or seams, which, in some instances, give rise to an obscure prismatic structure. These seams becoming widened by the action of the weather, and many of the separate masses, owing to their more perishable nature, having been disintegrated and removed, many of the peculiar features of the granite, already described, are thus produced.

A very interesting variety of these seams is met at Chundergooty, on the north-western frontier of the Mysore country. A small range of low undulating hills is composed of the common curved laminar granite; the laminæ of which vary from several feet to a few inches in thickness. Parallel to the direction of the range, namely, south by west, the granite is divided by vertical seams, which maintain the most perfect parallelism throughout their whole extent; and thus, were we to leave out of consideration the laminar structure, they might be said to divide the

* Bellary Hill, some of the hills at Annagoondy, and Moul Alley Hill, near Secunderabad, are good examples of these appearances.

hill into regular vertical strata. The superficial laminæ have, in many places, separated at the seams, and, by exposing those below, have afforded a proof that the seams extend through the whole mass of the hill. This granite is, in some places, penetrated by small veins of quartz, which, on approaching a seam, leave their original direction, follow the course of the seam for a greater or less distance, and again abruptly leave it.

The two surfaces of the laminæ are often perfectly parallel; and when they are not of a great thickness, they can be very easily raised in slabs of any size for architectural purposes. It is seldom, however, that they are of precisely the same thickness for any great extent; and sometimes this varies prodigiously within a very short distance. In some instances of this description, the granite loses its laminar appearance. Thus, when a lamina becomes very rapidly thinner, so that its two surfaces meet, it acquires the shape of an immense wedge, which is not unfrequently met with. In such cases, the term laminar is rather inapplicable. At the same time, it must be remembered that these are extreme instances, which are connected by many intermediate links to the most perfect form of this structure. Although, therefore, we would not apply the term laminar to these cases individually, yet it is perfectly evident that it is quite accurate as a general term, applied to the prevailing structure of the granite of India, and that, when we analyse the various appearances which the granite presents, they may be all considered as varieties and modifications of this structure.

There are several instances, in the Hyderabad country, of huge natural columns, formed of four or five separate masses of granite, piled with great regularity on each other, with part of their surfaces accurately adapted. These, in some instances, occupy the summits of gentle hills, and, from all the appearances connected with them, it is perfectly clear that the different masses continue to occupy their original situations. The following is probably the manner in which this curious appearance has, in many cases, originated. In a hill of laminar granite, it is evident that if the laminæ be liable to be split and disintegrated by the action of the weather, those parts which rest on the sides would be more liable, from their inclined position, to be worn down, and to slide into the neighbouring valley, than that part which rests horizontally on the summit; and were the upper mass to be left, it would protect the portions immediately below it, while the other parts were gradually disintegrated and removed; and thus a rude column, composed of a number of separate blocks of granite, would be formed. As the different masses rest horizontally on each other, and have their surfaces (except where these have been much acted upon by the weather) accurately adapted to each other, we cannot for a moment suppose

that they have been conveyed from a distance, and arranged in this manner merely by chance. On the other hand, we have every reason to conclude that they are the slight remains of laminæ, the other parts of which have been gradually worn down all around them ; and that they now stand as monuments of what the height and nature of these laminæ formerly were.

It is by no means uncommon to meet with a vein of quartz, felspar, or trap, passing from one loose block of granite into another, or from a hill into a mass resting loosely upon its surface ; which clearly proves that these continue to occupy the situations in which they were originally formed. Upon a superficial view, one is naturally led to suppose that the confused heaps of granite blocks are the result of some great convulsion of nature. But by merely tracing the small veins of quartz, felspar, &c. which traverse the granite from one contiguous block into another, and by attending to the accurate adaptation of some of the contiguous parts of these blocks, we can prove that a great proportion of them continue in their original situations; and that all the appearances of confusion which they exhibit are the result of a partial and irregular disintegration. It is only in the valleys that transported masses are found. We have generally reason to conclude that all the separate masses, on the sides and summits of the hills, continue to occupy their original places, however confused these may now appear.

We have no reason to suppose that all the granite which has been disintegrated and washed away was of a hardness and durability equal to that of the masses left entire. Had this been the case, their destruction would have required a length of time which our imagination cannot embrace. But, it is quite evident, that the perishable granite of loose texture, which is so very common, has alone been removed; and this removal, by depriving the more solid masses of its support, has caused many of them to split, and be precipitated into the neighbouring valleys.

The distribution of the perishable granite is often very irregular; and, in this case, when removed it must necessarily leave the solid masses with which it was associated in the most fantastic situations, and thus we can imagine how many of those appearances of confusion met with in the granite of India may have been produced. We can sometimes perceive how the original laminæ might be renewed by filling up the void spaces between the different masses, and thus connecting together what were formerly distinct portions of the same laminæ.

In regard to the mineral composition of the granite, it may be said (speaking very generally) to consist of felspar, quartz, mica, and hornblende ; but it is very seldom that all these ingredients are found associated in one specimen. Sometimes one ingredient, sometimes another,

is wanting, which produces a very great number of varieties. By far the most common is that composed of quartz, felspar, and hornblende, the sienite of Werner. The felspar is in some instances white, in others red. A great part of the Indian Peninsula, therefore, consists of a rock precisely similar to that found in the famous quarries in Egypt, and it has the same geognostical situation, for we are told by Daubuisson* that the latter, like the Indian rock, is associated with granite.

The ingredients vary very much in their proportions and colour, and thus produce varieties that occur within a short distance of each other, in the same lamina. One variety is sometimes found passing imperceptibly into another, penetrating it in the form of a vein, or imbedded in the form of a nodule.

A very interesting variety is found associated with the granite at Roan, in the Darwar district.† It consists of a very dark red felspar, with small disseminated crystals and minute veins of quartz; and, what is curious, there are numerous small vesicular cavities throughout the felspar, some of which are lined with very minute crystals, apparently of chlorite. It would be interesting to ascertain the exact relation which this rock bears to the granite, a point which I myself had not an opportunity of examining.

A very beautiful rock is found associated with the granite at Gudjunderghur. It is a sort of greenstone porphyry; the basis being greenstone, and containing large crystals of red felspar.

The Indian granite is generally small granular. I have only seen one specimen of large-grained granite in India, which had been brought from Mysore, and was composed of felspar, quartz, and mica.

At the falls of Garsipa there is a variety of granite, which differs from the common granite of India. It is not so old a granite as the latter; is composed of small grains of white felspar, quartz, and mica; has, in some instances, a slaty appearance, and is associated with gneiss and hornblende schists. These rocks, being perfectly bare, can be very easily examined.

They all occur within a space of a few hundred yards. I observed several varieties of the hornblende rock. One consists almost entirely of hornblende; a second contains disseminated crystal of felspar; a third contains mica and felspar; a fourth has more of the characters of actinolite than hornblende; and a fifth contains so much mica that it appears to be almost entirely composed of it. All these varieties, with the gneiss and granite, pass insensibly into each other. They are distinctly stratified, have a dip of about 30°, and their direction is nearly ESE. They form the sides of the chasm, over which the river is precipitated at the

* Traité de Geognosie, tom. 11, p. 20.

† I am indebted to Walter Elliot, Esq. for the specimens of this rock which I possess.

falls of Garsipa; and the depth of which, as already stated, is nearly 1,000 feet. This is the only place in India where I have met with primitive gneiss: but it is not improbable that it occurs in many other parts of the country. We are told by Dr. Davy that the greater part of Ceylon is composed of it,* and it is also found in the Himalayas.†

Quartz veins are very common in the granite. They are sometimes so small as to be capable of being exhibited in hand specimens. Sometimes they are of such a magnitude as to form ranges of hills, which may be recognized at a great distance by their white colour. These hills appear to have originated from the indestructible nature of the quartz having enabled it to withstand the attacks of the weather; while the more perishable granite was worn down all around it. There are two conspicuous ridges of quartz which appear to have been formed in this way, in the vicinity of Hyderabad. One is near the British Native Cavalry lines; the other is near the town of Shumsabad. Drusy cavities, lined with very beautiful amethysts and rock-crystals, are sometimes found in these hills. The granite, in the vicinity of these veins, often passes gradually into the quartz, by losing its other two ingredients.

Trap is very common throughout the granite tract of India. It is found both in veins and in extensive overlying masses.

The veins which traverse the granite present two distinct kinds of trap. One is precisely similar to the most common kind of the secondary or overlying trap, viz. a greenstone of a perishable nature, and having a concentric lamellar structure. It therefore most probably belongs to that formation. The other is more compact, has a rhomboidal structure, occurs generally in smaller veins, and is much more durable.

Large accumulations of granitic *débris* are met with all over the granite tracts of India. In many places this *débris* is so completely consolidated, simply by means of the aggregation exerted between its particles, as to form a hard rock.‡ This rock, in some instances, exhibits an obscure schistose structure.

Granite is not generally employed as a building stone in India, on account of its great expense; but large slabs of it are sometimes brought into the bazars for sale by the Wudras,§ and are used for paving the floors of the verandahs in the better sort of native houses, and other similar purposes. It is also hewn into hand-mills, for grinding

* Vide Transactions of the Geological Society of London, vol. v. p. 314.

† Vide do. do. new series, vol. i. p. 132.

‡ Kirwan mentions an instance of an artificial accumulation of granite sand having so completely consolidated, by means of a simple aggregation between its particles, as to form a rock so hard as to be impenetrable by water.

§ A vagrant class of people, somewhat resembling the Gipsies.

corn; two or four of which are a load for an ass or a bullock; and are thus carried to the bazar for sale.* These are the primeval mills of all countries which are mentioned in Scripture, and are still common among all uncivilized nations.

The ancient Hindoo temples at Anagoondy, now partly in ruins, are built of grey granite, or rather sienite. The massive and gloomy style of architecture, which characterises all Hindoo buildings, is also met with here; but in one instance it has, to a certain degree, been departed from, for in one of the principal buildings there is an extensive colonnade, the columns of which are light, with small pedestals and capitals, and approaching somewhat in their proportions to the Grecian. Some of the pillars are tastefully carved with flowers. A few are in the form of caryatides. They support immense slabs of granite, which are carved on their under surface, so as to form an ornamental roof. The largest of these slabs, which are in the central part of the building, are at least 30 feet long.† The laminar structure of the granite has probably been taken advantage of in the formation of these slabs; for a slab of almost any thickness may be easily detached from its native situation, and then cut into the required form, and of the necessary length and breadth.

It would appear, from a paper by Dr. Kennedy, in the eighth number of Brewster's Journal, that the natives of India have a method of polishing granite, which communicates to it a black colour. In this, I am pretty sure, he must have been deceived, and that he has mistaken trap for granite. Trap is extensively used in India for architectural purposes, and for statuary. Most of the temples at Anagoondy, as already mentioned, are built of grey granite, which perfectly retains its natural colour. Some, on the other hand, are built of greenstone, and are consequently black.

The Hindoos polish all kinds of stones by means of powdered corundum, mixed with melted lac. The mixture, being allowed to cool, is shaped into oblong pieces, of three or four inches in length. The stone is polished by being sprinkled with water, and at the same time rubbed with these oblong masses; and the polish is increased by masses being used successively with finer grains.

Transition Rocks.—These rocks occupy a very large part of the Darwar and Canara districts, and of the territory of Goa. They extend

* This brings to mind the following passage of Virgil:—

> "Sæpe oleo tardi costas agitator aselli,
> Vilibus aut onerat pomis: *lapidemque revertens*
> *Incusum,*" *&c.*

† I cannot positively state their exact length, for I attempted to ascertain it simply by pacing across the building; but I am confident they are not less than 30 feet long.

from the eastern and southern parts of the Darwar district, where they succeed the granite, to the western foot of the Ghàts, being, in a few spots only, interrupted by the granite, which protrudes from beneath them. On the coast they are concealed by the ferruginous claystone; but, in a few places, are seen cropping out from beneath it. In some parts of the Ghàts they are covered by the same claystone, and by trap rocks. In the northern parts of the Darwar district, they are only seen in the botton of the valleys, which intersect the sandstone hills. In the central and southern parts of the district they are only covered by the black soil, called cotton ground, which there forms extensive plains, and will be afterwards described. To the west of Darwar the transition rocks form parallel ranges of hills, having a general direction of south-east, which is the same as that of the strata of which they are composed.

The principal rocks of this series are clay-slate, chlorite-slate, talc-slate, limestone, grey-wacke, gneiss, and quartz rock. The strata appear to have a general direction of north-west and south-east. They are generally highly inclined, and, in many instances, quite vertical.

Clay-slate.—A great many varieties of this rock are met with in these districts. Its principal colours are grey, blue, greenish, red, and white. The grey variety appears to be the most common. I have met with it near Kulladghee, a few miles from Darwar, at Hoolgoor, along the river Mulperba, and in Soonda. At Kulladghee it contains beds of white quartz, in which I found specimens of copper-green. It has sometimes a greenish colour, and a blue variety is occasionally associated with it, which very much resembles roofing slate; but has seldom its hardness. It is also associated, in some places, with a rock closely resembling the grey-wacke slate of the south of Scotland.

The red and white varieties of the clay-slate occur in very considerable abundance in these districts. They extend for several miles around Darwar, where they are associated with quartz rock. They are found a little to the north of Kulladghee; and I met with them also near Holvully in Soonda. They may be said generally to consist of felspar, more or less coloured with iron, and having a loose aggregation. Some varieties, however, are intimately mixed with quartzy particles, which gives them a great degree of hardness; and they thus gradually pass into the quartz rock with which they are associated. The white variety is frequently so pure, that, in hand specimens, it would at once be pronounced to be a pure porcelain earth. This variety is found in great abundance at Darwar; and it might, I have no doubt, be very advantageously quarried for the purpose of being manufactured into porcelain ware. It has an obscure slaty structure. The red varieties with which it is associated are distinctly slaty. There is a gradual

transition from the purest white kind, to those having a deep red or brown colour. A light purplish colour is also sometimes met with.

At Darwar, these rocks are distinctly stratified. The strata are nearly vertical; and their direction is north-west and south-east. No single variety forms a continuous bed of any extent; but, on the contrary, several varieties are often found within a very short distance of each other, in the same stratum, and they are almost always traversed by thin veins of a brown quartz. In addition to the strata seams, these rocks are generally traversed by other parallel seams, which cross the strata, and thus, in some instances, give rise to large rhomboidal masses. So parallel and distinct are these transverse seams, which are seen in some of the large wells at Darwar, that they might, on a superficial view, be readily mistaken for the true stratification.

Owing to the soft nature of these clay-slates, wells can be very easily dug at Darwar; and several that were dug, during my residence there, to a depth of at least 70 feet, afforded me opportunities of studying the nature of the strata. Sometimes the red, sometimes the white variety occurs at the surface; and I have found the latter at a depth of 70 feet. Some of the varieties, when weathered, assume an ochre-yellow colour.

A fine display of these varieties of the clay-slate occurs in the bed of a ravine near Kulladghee. They there alternate with beds of grey-wacke. They have a very highly inclined, and, in some places, a vertical dip; and their direction is about north and by west, south and by east. In the dry season they can be very easily examined; for they are completely exposed for an extent of probably a quarter of a mile, except in a few spots where they are covered with *débris*. In those parts of the ravine where they have been worn down and polished by the stream, their red, blue, and white colours produce a beautiful appearance.

Chlorite-slate.—This rock is very widely distributed throughout these districts. It is met with throughout the whole of the central and southern parts of the Darwar district, in the Ghàts, and at several points on the western coast, under the clay-stone conglomerate. Its most common colour appears to be light greenish-grey. In the Ram Ghàt I found it with disseminated grains of felspar, and having a fine slaty structure. There is a variety found near Darwar and Kittore, which is intermediate between chlorite-slate and clay-slate. It has a bluish-grey colour, a slightly greasy feel, is hard, and has a coarse slaty structure. When tolerably compact, it is employed as a building stone, for which it is well adapted.

Some varieties of the chlorite and clay-slates contain crystals of iron-pyrites. I have been informed that this mineral is sometimes sent all the

way to Madras, by the native merchants, as an article of trade, I believe for the purpose of being cut into beads and other ornaments used by the natives.

Talc-slate.—This, like the chlorite-slate, has a very wide distribution throughout these districts. There are several varieties of it. The talc sometimes occurs unmixed with any other substance. It has, in this case, a fine slaty structure, and a greyish or reddish colour. This variety I found a few miles from the falls of Garsipa. Most frequently the talc is mixed with quartz; and the rock has then the general appearance of mica-slate, excepting the difference in the characters of the two minerals. This variety occurs in the central parts of the Darwar district, and in the Western Ghàts. At Nurgoond and Chick Nurgoônd, the strata of this variety have a nearly vertical dip; and their direction is south-east and by south.

Potstone is found associated with these rocks in the south-east part of the Darwar district, and is used by the natives for the manufacture of various utensils. The soapstone, which is sold in all the bazars, is probably also obtained from the same formation; but I myself have never seen either it or the potstone *in situ.**

All the fine plaster with which the walls of the houses are covered in India, and which is so much admired by strangers, is composed of a mixture of fine lime and soapstone, rubbed down with water; when the plaster is nearly dry, it is rubbed over with a dry piece of soapstone, which gives it a polish very much resembling that of well-polished marble.

Limestone.—I have met with limestone only in the north-east parts of the Darwar district. Numerous large beds of it occur about Kulladghee and Bagulkote, where it is associated with clay-slates and greywacke. Its strata are highly inclined, and their general direction appears to be north and by west, south and by east. The principal colours of the limestone are yellowish-grey and blue; more rarely it approaches to white. Its fracture is generally flat conchoidal. One of the varieties, from near Bagulkote, answers well as a lithographic stone, for which purpose it has been used at Bombay.

Grey-wacke.—This rock, as already stated, is associated with the clay-slates and limestone at Kulladghee; it also occurs in some other parts of these districts. Most of the coarse grey-wackes there have not the hardness that usually belongs to the same rock in Britain; but, on the other hand, they partake of the loose aggregation of the clay-slates with which they are associated. I have met with *grey-wacke slate* on the Mulperba and in the southern parts of the district.

* I am indebted to Walter Elliot, Esq., for the specimens of potstone which I have, and which he took directly from the quarries.

Gneiss.—All the transition gneiss that I have met with in the Darwar district was weathered; and, at first sight, therefore, it closely resembled a loose sandstone. It occurs in large quantities at Dummul, and beds of it are also met with at Nurgoond, associated with talc-slate.

Quartz Rock.—Beds of quartz are found among all the other transition rocks in these districts; and, in some instances, they are very large. It also occurs in all of them in the form of veins.

In the whole of that tract of country, extending from Darwar to beyond Kittore, and which is characterized by its parallel ranges of hills, the quartz occurs in large beds, which are almost invariably found forming the summits of these ranges. This circumstance enables us to account for the hills being parallel to the strata of which they are composed, and, consequently, to each other. The durable nature of the beds of quartz has caused them to resist the attacks of the weather, while the soft clay-slates with which they are associated have gradually given way. The valleys have thus been scooped out between the parallel beds of quartz rock, which we find forming the summits of all the hills; their flanks and the bottoms of the valleys consisting of the softer and more perishable clay-slates.

The quartz of which these beds are composed is in general deeply coloured with iron. Some varieties, however, have a grey colour, a splintery fracture, and closely resemble hornstone. It has often a uniform brown colour; and some specimens contain so much iron as to increase considerably their specific gravity. In many instances the base of the rock is white or grey, and is traversed in all directions by dark brown-coloured veins highly impregnated with iron. But, in some specimens, the dark brown variety is in much larger quantity than the white basis; and then the latter appears as if it had been broken into a number of small angular fragments, which had been afterwards united by the consolidation of the brown variety from the fluid form. This variety contains numerous small cavities, which are lined with red hæmatite in the shape of stalactites, or having a blistered or mammillary form. The cavities are generally very small; but I have seen very large specimens of red hæmatite which were found in the Kupputgood range. Brown hæmatite is also sometimes met with, but it is not so common as the other.

I may here mention, that I found a large bed of a variety of compact magnetic iron-ore, on the summit of a small hill, near Hitnal,* a village in the Hyderabad country. It is associated with mica-slate and quartz rock; and the base of the hill consists of granite.

Old Red Sandstone.—This is one of the most extensive formations in India. It forms the summits of most of the Eastern Ghàts. It extends

* Hitnal is about ten miles to the east of Copal.

over a great part of the district of Cuddapah, occupies extensive tracts in the Deccan, forms the summits of most of the hills in the Vindhya and Gondwana ranges on both sides of the Nerbuddah, and extends over part of Bundelcund, and even as far as Delhi.

The old red sandstone occupies a large tract of the districts, the geology of which forms the subject of this paper. From Gudjunderghur, where it rests immediately upon the granite, it extends north and north-east, as far as the Kistnah, occupying all the north-east corner of the Darwar district, and extending some way into the Hyderabad country. From thence it stretches across the country to beyond Gokauk, occupying all that tract which has been already pointed out in a former part of this paper. It also forms the summits of three insulated hills in the centre of the district, namely, the hills of Noulgoond, Nurgoond, and Chick Nurgoond. On all of these three hills, it forms large tabular masses, the sides of which form mural escarpments all round ; and from the bottom of these escarpments the hills have a gradual slope to the plain below. At Noulgoond the sandstone rests on granite ; on the two latter hills it rests on the talc-slates of the transition class.

From Gudjunderghur to Badamy, and in all the hills south of the Mulperba, the strata of sandstone are almost universally horizontal. The hills are all very nearly of the same altitude, are in long ranges, having even summits, and, when seen from a distance, they look like huge natural walls.

North of the Mulperba, the strata of sandstone are in general more or less inclined ; and they appear to rest there unconformably upon the transition rocks, namely, the clay-slates, grey-wacke, limestone, &c.

In regard to its mineral composition and structure, this rock varies exceedingly. It occurs under the forms of a coarse conglomerate, a coarse sandstone, and different varieties of compact quartz. Its most common colours are red and brown ; and it is frequently variegated with white.

At Gudjunderghur, and in the hills which extend from that place to Badamy, it is in the form of a very coarse sandstone. It there consists, generally speaking, of grains of quartz cemented together by means of clay. Sometimes the quartz is in large rounded or angular masses, thus forming a coarse conglomerate. Generally, however, it is in smaller grains of uniform size, forming a coarse sandstone. Its general colour is red. Sometimes it is variegated with white ; the white being in patches, or in straight or waved lines ; and I have seen large round nodules of white imbedded in the red base.

To the north of the Mulperba the quartz, or compact variety, prevails. It has a splintery fracture and brown colour. In many instances it is traversed in all directions by white veins. It is, in many places,

associated with puddingstone, which occasionally forms very large beds. In the hills of Nurgoond and Chick Nurgoond, both the arenaceous and compact varieties are found very near each other. In one part of the latter hill, the compact variety has, on the large scale, somewhat of a spheroidal structure. In the south-east part of the Nurgoond hill there is a large mass of a diaphanous quartz with a bluish colour, and disseminated grains of felspar. This variety is by no means uncommon, especially in the hills south of Kulladghee, where it has sometimes a reddish or white colour.

Some geologists might be disposed to arrange this sandstone with the old red sandstone of English geologists (transition red sandstone of the Germans); but I am inclined to consider it identical with the old or new red sandstones of the Wernerian geognosy; and, therefore, as very generally disposed in an unconformable position in regard to the transition rocks. I will now, therefore, state, as briefly as possible, the circumstances upon which I rest this opinion.

First.—In many parts of the Darwar district the sandstone hills have horizontal strata, level summits, and, for many miles, exactly the same altitude; while at one part we find granite, at another part transition rocks, immediately at their bases.

Secondly.—On the south-east declivity of the small hill of Chick Nurgoond, the schists are not covered by *débris*. Their dip is vertical, and their direction nearly north-west by west. They can be traced to within a few feet of the sandstone, which forms the summit of the hill, and which dips towards the north-west, at an angle of about 40°.

Thirdly.—A small range of sandstone, or rather quartz hills, near Kulladghee, is divided in several places by ravines. In walking up one of these ravines, you have the quartz hills on both sides, and can observe their strata inclined at a small angle, while the bed of the ravine along which you walk consists of the clay-slates and grey-wackes, which are found in all the low parts of the adjoining country, and the strata of which are mostly vertical.

I have never seen the sandstone conformable to the transition rocks; but I do not mean to say that this may not sometimes be the case. The above observations, however, are, I think, quite sufficient to show that it is very often unconformable, and may belong to one or other, or include both the red sandstones of the Wernerian geognosy.

The following striking appearances are presented by the sandstone of Badamy. The hills at that place, composed to their very bases of sandstone, have perfectly even summits, and are surrounded on all sides by vertical precipices, descending, in many instances, completely to the valley, which is covered with fine sand, the *débris* of the adjoining hills. The sandstone strata are generally horizontal. The precipices

have a height of probably 200 feet;* and the hills are, in many places, completely divided by rents from top to bottom, and are thus separated into a number of huge, distinct masses. Some of these masses which are next to the plain have a slight inclination forwards, and appear as if a very slight force would be sufficient to occasion their complete degradation.

The two small forts of Badamy are built upon these precipitous sandstone hills. Next the plain these forts are protected by a precipice of 200 feet, and, on the opposite sides, they are defended by deep rents, which separate them from the adjoining parts of the hill. The only access to the forts is up through the rents already mentioned. Upon entering these at the bottom, you have on each side of you immense walls of rock, from 100 to 200 feet high, and affording a passage of only a few feet in width. The rents are less deep as you advance; and the ascent is generally by means of steps cut in the solid rock.

A cave, the roof of which is supported by pillars, and the sides carved with representations of some of the Hindoo deities, is excavated in the sandstone of Badamy. It is not, however, to be compared, in point of size, with the caves of Elephanta or Ellora.

Secondary Trap Rocks.—Trap rocks occur very extensively in different parts of India. They are met with in some parts of Mysore and Hyderabad. They occupy a very large part of the Deccan, extend from near Fort Victoria on the western coast northward beyond Bombay, stretch thence across the country through Kandeish into Malwa, and are also met with in Bundelcund and Marwar.†

In the Darwar district they do not occur in great abundance. The great formation of trap, which extends all the way from the northern parts of the Deccan to the south of the Kistnah, terminates here, and the trap hills to the south and east of Belgaum probably form its boundary in that direction. It is, therefore, in the north-western part of this district that the trap is principally met with. I must also mention, however, that I found a compact greenstone at Sedasheghur resting upon granite; but I am inclined to think that it does not belong to the secondary trap which we are now considering, but to a much older formation.

The trap in the neighbourhood of Belgaum forms rounded hills, and does not exhibit the appearance of steps of a stair, which characterises the trap in other places. It is also found in the form of veins travers-

* I state this only from memory; it must, therefore, be considered merely as an approximation.

† Vide Mr. Fraser's paper in the first volume of the Geological Society's Transactions, new series.

ing granite, in some parts of the Hyderabad country. A very large vein of secondary greenstone is found traversing the granite at the village of Mussaputtan, near Anagoondy. It is so large as to form a small range of hills, which, being nearly bare, can be recognised at a great distance by their black colour.

The most common rocks which occur in this extensive formation are, a loose greenstone, basalt, and amygdaloid. The first, which appears to be the most common, has a concentric lamellar structure, the lamellæ separating very easily from each other, and becoming harder towards the centre, which contains a hard nucleus. Sometimes this variety has a rhomboidal structure; but, in this case, each rhomboid is found to have the concentric lamellar structure in its interior. This greenstone is almost always weathered to a very great depth. It is, therefore, very difficult to get a fresh specimen. When weathered, it has a grey colour; when fresh, it is found to be composed of distinct grains of felspar and hornblende.

The compact varieties of greenstone are very much employed in India as building stones. Most of the magnificent mosques and mausolea at Beejapore, which is situated in the midst of the trap formation, are built of it.

I found basalt at the village of Baugwarry, twelve or fifteen miles east from Belgaum. It contains small vesicular cavities, which appear never to have been filled with any substance.

I have never seen the amygdaloid *in situ;* and it does not appear to be common in the Darwar district. Specimens of it have been brought to me from the neighbourhood of Beejapore. They contain zeolites, green earth, and calcareous spar; and resemble the same rock in Britain.

Ferruginous Claystone.—This is the laterite of Buchanan. It covers very large tracts, both in India and the neighbouring countries. It extends all along the Western Coast, from Fort Victoria to the southern extremity of the Peninsula.* It occurs in great abundance in the Deccan, in Mysore, in the district of Cuddapah, and in Orissa.† It is met with also in Ceylon, and is almost the only rock which occurs in Malacca.‡

This rock may be described, generally, as consisting of claystone, more or less impregnated with iron, and having a massive, perforated, or cellular structure. It frequently contains, imbedded in it, small masses of clay, quartz, or ironstone. In its native beds a short way under the surface, it is so soft that it can be easily cut with a hatchet or

* Vide Mr. Calder's paper in the Asiatic Journal for October, 1828.

† Vide Asiatic Researches, vol. xv. p. 177.

‡ Vide Finlayson's Mission to Siam and Hue, p. 37.

spade; and, when sufficiently compact, and not containing imbedded portions of quartz, &c. it is cut into square masses like bricks, and is used as a building stone. Hence Buchanan gave it the name of laterite; and its names, in the native languages, are derived from the same circumstance. When these square masses are exposed to the air for some time, they become very hard; and, when not exposed to constant moisture, they answer admirably as building stones. Most of the handsome Roman Catholic churches at Goa are built of this claystone, or laterite. In the principal fronts of these churches it is covered with plaster; but in other parts it is left bare, and completely retains its hardness when exposed to the atmosphere.

The ferruginous claystone occurs in different parts of the Darwar district; but principally in the western parts, and on the summits of the Ghàts. Scarcely any other rock is seen in the Goa territory, and it extends almost uninterruptedly from Goa to Honoor. It is found resting in different situations, on granite, transition rocks, trap, and sandstone. It is a very curious and interesting circumstance in regard to the geognostical situation of this rock, that it is found resting upon granite and transition rocks along the coast, and is again found resting upon the same rocks at the summits of the Ghàts, at an elevation of several thousand feet. It forms, along the coast, a succession of rounded hills; and, towards the sea, it generally presents mural precipices. I have never seen beds of any other rock alternating with it; and it is nowhere stratified. Sometimes it forms table-shaped masses on the summits of the Ghàts; and where it is split into separate masses on the coast, these have sometimes an obscure cuboidal form. It may be said, however, to have no distinct structure, and merely to form enormous overlying masses, which extend over a very large part of the Peninsula of India.

In some places the claystone contains numerous small nodules of clay iron-stone, which seldom exceed the size of a walnut. These are picked up by the natives, and are smelted by meansof charcoal in a very small rude furnace, blown by the hand-bellows, common all over India, and still used in Europe by the Gipsies. If any profit can be obtained from such a very rude and tedious process, to what good account might not the rich ores of hæmatite and magnetic iron be put?

Many of the hills composed of this rock are nearly devoid of vegetation; their surface being bare and smooth, and of a red or black colour. The soil produced by its disintegration is not very productive; and so liable is it, in some places, to consolidate, when deprived of its moisture, that, if it be not constantly cultivated, it soon becomes hard and bare, and checks all vegetation.

I have seen no secondary rocks in India above the old red sandstone, except the trap and ferruginous claystone. Dr. Adams mentions that he found rolled pieces of coal in the bed of the Towa river, which falls into the Nerbudda ;* but he did not see the coal *in situ;* and the existence of the coal formation, therefore, in the Peninsula of India, still forms an interesting subject of inquiry for future observers.

Cotton Ground.—Immense deposits of a black alluvial clay are met with in various parts of India. It is denominated cotton ground, from the circumstance of that plant being always cultivated upon it. It is the regur soil of the Ryuts. It forms large plains throughout the whole of the Deccan ; some of them sufficiently extensive to bring to mind the descriptions given by travellers of the Pampas of South America, or the steppes of Russia.

Its depth extends from 2 or 3 to 20 or 30 feet. Its colour is greyish-black or brownish-black. In many places it is perfectly unmixed with any foreign ingredient. In other instances it contains nodules of calcareous tufa,† agates, calcedony,‡ and occasionally also zeolites. In the hot season it is everywhere traversed by deep fissures, which, in some cases, have a great appearance of regularity, like that observed in dried starch ; but most commonly they are perfectly irregular. The late Dr. Voysey, when at Hyderabad, subjected some of this clay or cotton ground to the heat of a steel furnace, which fused it into a black glass.

The black colour of this clay, the carbonate of lime, agates, and zeolites found in it, and its conversion into a black glass by heat, all indicate that it has originated from the disintegration of trap rocks. The extensive distribution of the trap-rocks makes this inference still more conclusive. The soil which covers the trap-hills, and which we are certain has originated from the disintegration of the subjacent rock, exactly resembles the cotton ground of the extensive plains. Were this cotton ground to be again consolidated, it would form an immense overlying formation of a substance resembling basalt or wacké. Its very great importance in the agriculture of India will be considered hereafter.

Several deposits of calcareous tufa occur in the Darwar district. There is one of considerable extent near Badamy. It is covered by the soil, and appears to rest upon the transition rocks. Sometimes nodules of calcareous tufa are found disseminated through the cotton ground, and materially affect its agricultural properties. From its being thus associated with the cotton ground, I think it is highly probable that the

* Vide Memoirs of the Wernerian Society, vol. iv. p. 61.

† This substance is well known by the name of Kunker in India.

‡ The same circumstance is noticed by Dr. Adams in regard to the black soil of the Nerbudda Valley. Memoirs of the Wernerian Society, vol. iv. p. 52.

calcareous tufa has, in many instances, owed its origin to the calcareous spar of the trap-rocks, of those rocks the *débris* of which now forms the cotton ground. The tufa is used for the preparation of mortar.

In concluding these observations, I have much pleasure in expressing my acknowledgments to Professor Jameson for having corrected some of my observations, and for his valuable remarks upon my specimens of the rocks of the Southern Mahratta Country.

Notes, principally Geological, on the South Mahratta Country—Falls of Gokauk—Classification of Rocks. By Captain Newbold, F.R.S., &c. Assistant Commissioner, Kurnool.

[Reprinted from the Journal of the Asiatic Society of Bengal, vol. xiv. p. 268, *et seq.*—April 1845.]

The reader has already been introduced into the South Mahratta Country at its eastern angle near the confluence of the Kistnah and the Gutpurba.* We will now proceed westerly across it, following the right bank of the Gutpurba to the Falls of Gokauk on the eastern slope of the Western Ghàts, leaving the Kolapore territory to the right.

I crossed the Kistnah about two and a half miles below the *Sungum*, or confluence, and passed up the opposite bank towards the tongue of land formed by the junction of the rivers. The apex consists of silt, sand, and clay, in regular layers, rising, as they recede, to the height of about 16 feet above the surface of the wàter.

A section of these layers was afforded in the sides of a deep cleft running down to the Gutpurba. They present a striking illustration of the formation of fissures in sedimentary rocks, simply by the mass contracting in consolidation, unaided by subterranean movement or displacement, which we are compelled to call in to our assistance in explaining the great faults and displacements, attended with scorings of the faces of the fissures, and the polishings termed "slickensides," so common in the coal measures, and other old sedimentary rocks of Europe. Earthquakes, another cause of fissures, are unknown here.

The fissures in these layers of silt and clay are usually vertical, and widest in the more consolidated layers; their course is often zigzag, like that of the celebrated gap in the sandstone rocks of Gundicott through which flows the Pennaur, or like the fissures in the *regur* deposit; during the hot months they frequently intersect each other.

Horizontal seams, independent of the parallel laminæ of deposition, have been formed, partially filled with a titaniferous iron sand, which owes its arrangement and segregation in distinct layers partly to its greater relative specific gravity, and partly to the motion of the water.

The truth of this is easily illustrated by the simple experiment

* See Journ. vol. xiii. p. 1004 [and this volume, p. 83.—Ed.]

of mixing intimately some common quartzose sand with a portion of the iron sand, and throwing them into a tumbler a quarter full of water.

If the tumbler then be inclined to one side, and gently moved so as to cause the water to move backwards and forwards over the surface of the sand, the particles of quartz and iron gradually separate, and become arranged in distinct layers.

The upper beds of the section are of loose silt and sand, the lower layers are more consolidated, and towards the base of the cliff thin layers of an indurated liver-brown marl alternate; both the silt and marl effervesce slightly with acids. At the bottom of the fissure runs a rain channel, which has washed the sides into salient and re-entering angles. In some places they have been excavated and undermined by it, and portions of the superincumbent layers have fallen in. In short, we see on this diminutive, yet true scale, all the striking features of precipice, ravine, pinnacle, and castellated form so remarkable in the sandstone and limestone formations.

Tabular cavities appear in many portions of the cliff which have neither been caused by snails, nor other boring conchifers. They have originated from the stems of long grasses, around which layer after layer of silt, &c. had been deposited until the stem decayed away, leaving an empty cavity modified by the action of the rain trickling down it into the substance of the rock. In many of these cavities the grasses are still seen. The iron sand is slightly magnetic, infusible *per se* before the blow-pipe; and forming with difficulty a blackish slag; it tinges borax of a brownish green. It has probably been derived from the neighbouring trap formation.

The Rivers Kistnah and Gutpurba.—The Kistnah near the confluence is apparently about 500 yards broad, and the Gutpurba about 100. The current of the former had a velocity of about two and a half feet per second, and the latter about two and three quarters feet.

The temperature of both rivers, one foot below the surface, was exactly the same, viz. 76° 5′. Temperature of air in shade, 76°; in sun, 84°; month July, river swollen by the monsoon freshes. Mean temperature of the South Mahratta Country at Darwar, according to Christie, is about 75°. As both rivers were nearly full, there was no opportunity of examining the size and nature of the pebbles in the bed. On the banks are scattered water-worn fragments of chert, quartz, granite, trap, felspar rock, hornblende schist, jasper, lateritic conglomerate, kunker, ferruginous clay, greyish blue and sand-coloured limestone, sandstone, and calcedony. None of the fragments that had been transported by the current were more than three or four inches in diameter.

A tumblerful of the turbid water deposited about one-twentieth of its bulk of a fine sandy brown sediment, which effervesced with acids; very different, like those of the Bhima, Godavery, Tumbuddra, and Cauvery,

from the *regur*, which, as before mentioned, is supposed by some geologists to be a deposit of these rivers. The freshes of the Kistnah do not, according to the testimony of the oldest boatmen, ever overflow the banks more than half a mile; and its inundations at Danoor, and other places where I have crossed it, rarely spread to a greater extent. These facts argue strongly against the theory of the fluviatile origin of the *regur* which is seen covering vast flat plains like seas, which extend, I may say, hundreds of miles from the banks of these great rivers. With regard to Christie's theory of its being the detritus of trap rocks, I have before observed that the iron contained in them oxidizes, becomes ultimately reddish or coffee-coloured in weathering, and imparts its colour to the detritus; and that the alluvium we now see brought down by the Kistnah, Bhima, and Godavery, which rise in and flow over the great trap formation, is of a brown colour, very different from the bluish black of the purest *regur*. One of the richest and most extensive sheets of *regur* in Southern India is that of the Ceded Districts, which is watered by the Tumbuddra, Pennaur, and Hogri rivers, the courses of which on no point touch the trap formation, passing over plutonic and hypogene rocks, sandstone, and limestone. If the rich sheets of *regur* which cover the plains of Trichinopoly, Artoni, and Cuddapah, had been derived from the great trap formation, one would naturally expect to find in it, or associated with it, grains or fragments of calcedony, agate, jasper, heliotrope, and other hard minerals so abundant in the overlying trap; but there is no instance on record of such fragments having been found in these *regurs*.

The *regur* is seen, too, far above the present drainage levels of the country. At Beder, as already observed, both Voysey and myself found it on cliffs nearly 200 feet above the general level of the surrounding country.

The boiling-point of water at the Sungum was 200·3. Temperature of air at the time of observation, 80°.

On the south bank of the Gutpurba are some low hills running ESE. The only one which was examined proved to be a breccia, overlying the light blue and buff limestone, composed of a dark red or liver-brown clay, highly indurated, and passing into jasper, imbedding angular fragments of the siliceous portions of the subjacent limestone, chert, quartz, &c. The angular fragments of chert are often so small as to give this breccia the appearance of a porphyry, for which some portions of the rock might at first sight be mistaken, and a bed of really aqueous origin confounded with a plutonic rock—an error which has happened.

Proceeding westerly from the limits of the hypogene schists, the imbedded fragments in this breccia become larger, and the conglomerate character cannot be mistaken. It is evident, from the gradually increasing size of the pebbles, that the rock whence they were derived is neared

as we advance west, and that the current which deposited these beds of sand and pebbles must have had an easterly direction.

This inference proved correct; and the limestone was found *in situ* at a short distance west from the hills, on the south bank of the Gutpurba, in broken-up and dislocated strata; some of the limestone slabs had been furrowed as if by the action of pebbles passing along them in an east and west direction. Dark veins of chert projected everywhere from the water-worn blocks and slabs of this limestone, many of which are thickly encrusted with depositions of a ferruginous kunker which abounds. The limestone often abounds so much in silex, and is so indurated as to give fire with steel, and hardly effervesces with acids, save in a pulverized state. Marks of aqueous abrasion and plutonic disturbance, which preceded the formation of the breccia, are very apparent in this locality.

Sitadonga Hills.—A plain almost covered with *regur* extends from these low hills of breccia to the Sitadonga Range, which, abutting on and confining the Gutpurba on the north, run down to Badami and Gujunderghur on the south. The hills at this point consist of sandstone and conglomerates, the latter usually the lowest in position, both partially capped by a lateritic conglomerate, which, in many places, has evidently been stripped off by denudation. The conglomerates are often of a highly ferruginous and jaspideous character, and imbedding fragments of chert, quartz, and shales from the limestone.

As these hills are ascended, the sandstone gradually loses its conglomerate character, passing into almost all the varieties it is susceptible of, from yellow and reddish rock, containing much argillaceous matter, to a loose gritty sandstone with red and yellow bands, which passes into a compact white sandstone, approaching quartz rock, containing specks of oxide of iron, or decayed felspar, in minute cavities.

On the summit of the Pass was a fine whitish sandstone with reddish streaks, composed of grains of quartz held together by whitish decomposed felspar.

On many of the slabs the ripple mark is distinct, running nearly N. and S., which shows that the current must have had an easterly or westerly course in this locality. At the western base of the Pass the coloured argillaceous shales, into which the limestone usually passes near the line of junction with the superimposed limestone, have been invaded and cut by a dike of basaltic greenstone, and converted into reddish, greenish, and brown-coloured jasper and bluish-white chert in alternating layers, each line of which presents the original lines of deposition. Two other dikes, or ramifications, are crossed in the plain or valley extending from the base of the first Pass to another range, probably a spur or outlier of the ridge just crossed, and though curvilinear,

having a general direction nearly parallel with it. Green argillaceous schists, altered by the basaltic dikes, and in almost vertical laminæ, occupy the bottom of the intervening valley. The spur or outlying range is of a compact sandstone capping the schists, and dipping at an angle of about 28° towards the SW. Near the summit of the range it contains a bed of very fine white and red clay, which is extensively excavated by the natives, who use the former as a whitewash, and to paint the mark of caste on their foreheads.

The Gutpurba finds its way easterly through a break just below this rock, and rushes through the ridge just passed, by a still narrower and more rugged gorge.

Leaving the excavations, the traveller descends the sandstone spur into the extensive and fertile plain of Bagulcotta, based on limestone and its associated colöured shales and schists; bounded on the east by the Sitadonga or Gujunderghur Range; and, as far as the eye can reach, on the west by the ranges west of Kulladghur, and those of Gokauk on the flank of the Western Ghàts.

Plain of Bagulcotta.—This plain continues westerly to within a few miles from Kulladghi, watered by the Gutpurba on the north, and bounded by a long, low, flat-topped range, evidently of sandstone; to the S. the limestone, which bases it, has a general dip of about 25° towards the ENE. at Bagulcotta, and a direction nearly parallel to that of the sandstone ranges, viz. NNW.; both dip and direction, however, vary occasionally, probably from flexures and disturbanee by plutonic intrusion. The limestone in the vicinity of Bagulcotta and Kulladghi is of various shades and textures; sometimes as white and crystalline as marble, and composed almost entirely of carbonate of lime; at others siliceous or magnesian, or passing into whitish, green, blue, red, and chocolate-coloured argillaceous shales. At Bagulcotta a pale buff-coloured limestone occurs, portions of which might be applied to lithographic purposes; specimens of it, I believe, have been sent to Bombay for trial, but in consequence, probably, of not being selected properly, have been rejected as too hard, or for being veined.

The site I hardly conceive has had a fair trial; by the sending down a person *practically* qualified to select specimens, and by the quarrying a little deeper than has hitherto been done, I have little doubt that better samples of the stone might be got. Talicotta, however, as mentioned in a previous paper, is the most promising locality for lithographic limestone.

The purer white crystalline variety is broken up into small fragments, and burnt into lime. I observed in it the same green chloritic flakes which I afterwards found veining the marble in the quarries of Mount Pentelicus near Athens, and in the Cipolin marbles. A pale salmon,

or flesh-coloured subcrystalline variety, resembling Tirec marble, occurs both near Bagulcotta and at Sullakairy, a village about three miles S. from Kulladghi.

About three miles to the E. of Kulladghi a few low hills of a lateritic conglomerate rest on the limestone and associated shales, running parallel with the sandstone ranges. The cementing substance is partly a calcareous, and partly a clayey paste of a yellowish or reddish colour, imbedding nodules of laterite. The lower portions of this rock are more compact than the upper, and exhibit distinct lines of stratification. The range on the left, or south, of the road from Bagulcotta to Kulladghi, consists of sandstone and conglomerate. The latter imbeds pebbles both rounded and angular, from the harder and more siliceous portions of the subjacent shales and limestone, and also pebbles of an older sandstone, which I did not discover *in situ ;* these beds are not inclined so much as the limestone and shales on which they rest, but dip to the same point of the horizon.

Kulladghi.—The nullas in the vicinity of Kulladghi afford good sections of the limestone and its associated shales, which, from their highly inclined and bent strata, have evidently suffered much disturbance from plutonic forces. The frequent alternations we see of those rocks, in a very confined area, induces the supposition of the beds having been folded back upon themselves, and thus produced the appearance of a double and reversed alternation, the upper parts of the folded strata having been carried away by denudation, as is seen to be the case on the face of some of the magnificent precipices of the Alps.

The shales are beautifully marked by white, blue, green, yellow, and red coloured bands; and seamed with arenaceous layers. The open seams of the rock are often encrusted with kunkerous infiltrations.

Slate quarries of Katurki.—On the Maningpur road, near the village of Katurki, about one-half koss from Kulladghi, these slates split into rhomboidal forms by joints, and yield good hones; at Sullakairy tolerable roofing slates, slates and slate-pencils are quarried. Sullakairy, as before stated, is about three miles from Kulladghi, on the Gujunderghur road.

The lower beds of the quarried rock at Sullakairy are of a massive blue slate, interstratified with a softer, lamellar variety, easily fissile, and divisible into leaves, which are often not more than a line thick; dendritic markings are frequently seen on the surfaces of the laminæ.

From the more massive beds are hewn large blocks for pillars of pagodas, Hindu idols, &c. Roofing slates are not much patronized by natives, who prefer tiles, thatch, or mud, but considerable quantities have been here quarried and sent to the British cantonment of Belgaum

and the Portuguese Indian metropolis, Goa. The prices at the quarries, I was informed on the spot, for slates of a foot square and a quarter or half an inch thick, are five rupees per hundred slates ; they may be procured, however, of much larger dimensions, and of any degree of thinness. A capital writing slate and pencil were cut for me out of the quarries, shaped and polished all in a couple of hours.

A loose, friable, dark blue slate, in the bed of the nulla near the quarries, is sometimes pulverized and ground up with water, and used as a blue wash for houses, &c.

Iron Mines of Hirasillaky.—Iron ore is procured, according to native information, near the village of Hirasillaky, about two and a half koss from Kulladghi. The metal sells at from two to two and a half rupees the pukka maund of forty-eight seers. Land carriage by bandies or bullocks, and abundance of cheap fuel for smelting, are readily procurable.

From want of time and opportunity, my visit to the hone quarries of Katurki was by torch-light, when little was to be made out regarding the thickness or nature of the beds furnishing the Novaculites.

From Kulladghi to the Falls of Gokauk.—Proceeding in a W. by N. direction near the right bank of the Gutpurba, towards the falls of Gokauk, over extensive plains of *regur*, with patches here and there rendered sterile by saline infiltration (the muriate and carbonate of soda), the limestone and its associated shales are occasionally seen basing the plains intersected by dikes of basaltic greenstone, of which four were counted between Lokapoor and Hulkoond, about twenty-three miles distant from Kulladghi ; to the intrusion of these dikes much of the alteration seen in the limestone is attributable.

A little to the west of Hulkoond the great overlying trap of the Deccan is seen to extend over the surface of the schists, and may be traced nearly to the base of the sandstone cliffs to the south and west, covered by sandstone *débris ;* a few scattered sandstone outliers occur between Hulkoond and Kulladghi.

At Munnikerry, about twenty-six miles from Kulladghi, is a ridge of sandstone, approaching a quartz rock in compactness, intersected by a network of brown, ferruginous veins. The sandstone is, in some situations, covered with a breccia composed principally of sandstone and quartz in angular fragments cemented by a ferruginous clay. Close to a small pagoda, the sandstone at the SW. flank of the ridge near the edge of the overlying trap is penetrated with a vein of black manganese, associated with iron, about three inches broad.

At Bugganala, about two and a half miles westerly from this sandstone ridge, the limestone and shales are again seen dipping N. 20° E., direction of strata E. 20° S., layers and veins of a reddish jasper, and

chert intersect the limestone, a phenomenon that is usually seen where the limestone comes in contact with plutonic or hypogene rocks.

Farther west, between Bettighirry and Ooperhutty, a bed of quartzy talcose schist, approaching protogine, is crossed with layers of lithomarge.

Nearer Ooperhutty the overlying trap is again seen in low cliffs, on the banks of a nulla, resting on a red amygdaloid, which contains layers of a fine red bole with a shining streak, and conchoidal fracture. It does not adhere to the tongue; falls to pieces in water; does not form a plastic clay.

The trap is associated with wacke, with green earth in nests, and a chocolate amygdaloid, reticulated with strings of calc spar, and imbedding calcedony and zeolites.

A loose sandstone, associated, probably, with the laterite, and newer than that which has just been described, rests in horizontal partial layers on the trap, of which it imbeds small fragments.

On approaching the sandstone ranges of Cotabanghy and Gokauk, the hypogene schists are seen rising to the surface at their base, and the intervening limestone and its associated shales are wanting. The hill of Punchmi, to the SW. of the town of Gokauk, has a base of garnitiferous gneiss, hornblende and chloritic schists, capped with sandstone in massive beds. These beds are interstratified with layers of conglomerate, containing rounded and angular fragments of reddish quartz rock, quartz, and a greenish and grey chert. These fragments, in many instances, appear to have been deposited so tranquilly as to have been arranged agreeably to the laws of gravitation, and occur most frequently at the seams of the thick sandstone beds.

The hypogene rocks have a dip of about 60° towards the E. by N., direction of beds S. 5° E. The sandstone rests on it unconformably, dipping but slightly in the same direction. A dike of basaltic greenstone, of about five feet broad, penetrates the hornblende schist in an easterly direction, bifurcates at about the middle of the ascent from the NE., and is lost in the substance of the rock.

Falls of Gokauk.—The subordinate ranges of Gokauk and Cotabanghy, now before us, form the eastern flank of the Western Ghàts, and run in a parallel direction, here about S. by E. At Gokauk the upper portions of this range present mural precipices, with either well-flat tabular summits, or running in narrow-crested ridges.

They are entered from the east by a picturesque gorge (cross valley), through which the Gutpurba hurries from its mountain sources into the elevated plains of the Deccan, near the town of Gokauk, which is about three and a half miles easterly from the falls.

The road lay along the bottom and side of this defile on the right

bank of the river, which was now (July) swollen by the monsoon freshes from the Western Ghàts. It varied in breadth from 90 to 300 yards, presenting a rapid muddy stream, brawling and rushing from the alternate confinement and opening out of its rocky channel. It is unfordable generally during four months in the year at Gokauk, viz. from the middle of May to the middle of September, at the cessation of the monsoon. The water at the dry season ford, a little below the town, is now 15 feet deep. The sources are said to be near Bunder or Gunder Ghur, a little N. of the Ram Ghàt Pass from the S. Concan to Belgaum. After a course of about 100 miles, watering the plains of Kulladghi and Eagulcotta, it finds its way through the gaps in the Sitadonga hills just described, to the Kistnah, which it joins at the *Kudli Sungum.*

After an hour's time spent in winding up this rugged defile, the falls, the roar of which we distinctly heard during the silence of night at the town of Gokauk, at a sudden angle of the road became partly visible, presenting the magnificent spectacle of a mass of water containing upwards of 16,000 cubic feet precipitated from the tabular surface of the sandstone into a gorge forming the head of the defile, the bottom of which is about 178 feet below the lip of the cataract. The Gutpurba, a little above the fall, is apparently about 250 yards across, but contracts to 80 as the brink of the chasm is approached; consequently, the density and velocity of the watery mass is much increased, and it hurries down the shelving tables of rock with frightful rapidity to its fall.

The fall over the face of the precipice seems slow and sullen from the velocity of the surface water of this rapid, and from the great denseness of the body; and it plunges heavily down with a deep thundering sound, which we heard during the previous night at our encampment, three and a half miles farther down the river.

This ponderous descent, and the heavy muddy colour of the water, conveys a feeling of weight through the eye to the senses, which is relieved by the lightness and airiness of thin clouds of white vapour and amber-coloured spray, which ascend from the basin at the bottom of the gorge in curling wreaths, curtaining the lower portions of the fall, and through which the basin was only seen at intervals when its surface was swept by the fitful gusts that swept up the glen.

Rising above the cliffs that confine the falls, the watery particles vanish as they ascend; but again condensing, descend in gentle showers, which is felt at a short distance round the head of the falls.

Spray bows, varying in brightness, distinctness, and extent, according to the quantity of light refracted and the modification of the vapour, lent their prismatic tints to the ever-ascending wreaths; the largest, (observed about 4 P. M.) formed an arch completely across the river,

rose, and, receding as the sun sank in the west, gradually disappeared with it. Like the rainbow, they are only produced on the surface of the cloud opposed to the sun's rays. The size and distance from each other of the drops composing the different portions of the spray cloud evidently influenced the brilliancy of the refracted colours, the tints being brightest in those portions where the drops were of medium size and density, and dullest where the watery particles were smallest and closest together.

The velocity of the surface water of the rapid was about nine feet per second, and its depth ten feet. About two and a half miles farther up, the river near the village of Koornoor, beyond the rapid, is a ford in the dry season, and a safe ferry during the monsoon. A tumblerful of the turbid water deposited 1-50th of its bulk of a fine reddish clay, not calcareous,—a fact showing that the lime which exists in the sediment of this river at its confluence with the Kistnah, must have been derived from the intermediate plains. The pebbles brought down are chiefly quartz, granite, and from the hypogene schists, with a few of calcedony ; the sands containing grains of magnetic iron. The boiling point of water at the plateau of sandstone from which the cataract falls, gives 2,817 feet above the level of the sea.

The mean temperature of the place, approximated by Boussingault's method, is 78°, which I should think rather too high, as the temperature of a spring close by was only 75°. Temperature of air in the shade at time 78°.

The mean temperature of Darwar, which stands much lower, is calculated by Christie at 75°.

The head of the fissure, which is elliptical in form, with mural sides of sandstone, has much the appearance of having been cut back, like Niagara, by the abrading action of the water, for the space of about 100 yards. Large rocks, with angular unworn surfaces, evidently dislodged from the rocks on the spot, are seen in the bed, and on the sides of the river below the deep basin-receptacle of the fallen waters and on its margin. The great hardness and compact structure of the sandstone above the falls offer great obstacles to their rapid recession.

The cliffs, however, flanking the right side of the river below, are rent by nearly vertical fissures from summit to base, by one of which I descended to the bed. The direction of two of the largest was about ESE. They are crossed nearly at right angles by minor cracks, which thus insulate portions of the rock. The bases of these tottering pinnacles are often undermined by the action of the water, and the mass tumbles headlong into the stream.

The sandstone, in its lower portions, is interstratified with layers of shale, the softness of which facilitates this process of undermining.

These shales are of a purplish-brown and yellowish-brown colour, with minute spangles of mica disseminated, and, between the laminæ, contain incrustations of common alum (sulphate of alumina). The alum is earthy and impure, and sometimes has a mammillated surface resembling the alum incrustations in the ferruginous shales cresting the copper mountain near Bellary. It is found in considerable quantity in a small cave near the foot of the falls.

The ripple mark, so often seen on the sandstones of Europe, is observed in great distinctness on the tabular surfaces of the cliffs and in the exposed layers of the subjacent beds, at least 100 feet below the surface. Its longitudinal direction is various, but generally S. 25° W. indicating the ESE. and WNW. direction of the current which caused them. The ripple marks on the sandstones of Cuddapah and Kurnool have a general similar direction.

At the bottom of the deep fissures in the sandstone cliffs already described, accumulations have formed of fallen fragments of rock, sticks and leaves, &c. from above, intermingled with the dung and bones of bats, rats, and wild pigeons, with a few sheep and goat-bones. Some of the latter have the appearance of having been gnawed by hyenas, jackals, or other beasts of prey. Many, however, are evidently the remains of animals that have fallen from above, as the bones are fractured.

The upper portions of these fissures have sometimes been choked by rock and rubbish from above. Their sides, though generally smooth, are marked with shallow polished grooves.

I made two excavations through the floor of the principal fissure, in the hope of meeting with organic remains, but in vain. After penetrating the surface layer of loose stones and bats' dung, a fine red earth was met with, imbedding angular fragments of sandstone, and a few rounded pebbles of it and quartz. After digging for about four or five feet through this, farther progress was prevented by great blocks of solid rock.

The seeds of creepers and other plants vegetate on this soil, and shoot rapidly towards the surface, shading the fissures with their leaves.

On the cliffs near the falls, on the right bank of the river, stands a small group of Hindu temples dedicated to Siva. The principal shrine is a massive and elaborately carved structure of sandstone, elevated on a high, well-built pediment above the reach of the ordinary floods.

Seven years ago, three of the steps of the northern flight ascending this terrace were submerged by an extraordinary rise of the river. The *Vimana* of this temple contains the Phallitic emblem of Siva, the *Linga*, guarded by the sacred bull. Here we passed the heat of the day. On the opposite bank of the river rises a well-wooded hill, about 100 feet

above the brink of the rapid, on which stand a few ruins of other Hindu religious structures.

The table-land to the S. of the falls is covered with low jungle of *Mimosa*, *Euphorbia*, *Cassia*, and *Bunder*, the *Mend bundati* with its lilac sweet pea-like blossom, the *Carissa Spinarum*, *Webera tetrandra*, and other thorny shrubs. The *Euphorbia antiqua* and *tortilis* were in flower (July).

Tract between Gokauk and Belgaum, along the western slope of the Ghàts.—From the falls of Gokauk by Padshahpoor to the cantonment of Belgaum, about 34½ miles, the route lies nearly SW. across an elevated table-land sloping gently to the eastward, covered with alternating bands of red and black soil, generally well cultivated, and intersected from Padshahpoor, which is about 11½ miles from the falls, to Belgaum by curvilinear spurs and outlying hills, belonging to the Western Ghàt system, consisting of sandstone and sandstone conglomerates, as at Gokauk, in nearly horizontal strata. The ruins of the fort at Padshahpoor stand on a low flat-topped hill of this sandstone. This formation has been covered in two localities by the overlying trap. A little beyond the village of Kunnoor, about two miles from the falls, a narrow *coulée* of trap is crossed, containing olivine and dark glassy crystals of felspar.

About a mile to the NE. of Belgaum, another sheet of trap is entered on, which extends to the sandstone ranges on the right. The sandstone is now finally lost sight of on the line of route, and the trap continues the surface rock to Belgaum, where it is covered by a thick bed of laterite, over which is, in some places, superimposed a layer of the more recent lateritic conglomerate.

Sections of these rocks are afforded by the quarries near the old European Barracks, none of which have been excavated to the subjacent trap. It has, however, been dug down to in some of the deepest wells of the place. The laterite is used here as at Malacca, Goa, and on the Malabar Coast, as a building stone.

The trap in the vicinity of Belgaum rises into hills with rounded summits, covered in general with a dark, spongy mould, which is boggy during the monsoon, the grassy and almost treeless surface of which affords a strong contrast to the jungle-covered hills of sandstone to the NW. The trap hills are rarely flat-topped, or in horizontal ranges, as seen in the more central parts of its area. The trap at the summit of these hills is usually dark, compact, and basaltic, but occasionally contains almond-shaped and spheroidal cavities filled with calcedony and crystallised quartz, zeolites, and green earth. Black crystals of augite are occasionally seen shooting through its structure, which decay sooner than the imbedding rock; and, falling out in the state of powder, leave

numberless cavities on the surface. The rock itself, in weathering, resembles iron in rusting, and passes into reddish-brown, or coffee-coloured earth, or clay. Cavities occasionally are seen filled with a black earth resembling black bole.

SE. Boundary of the overlying Trap at Baugwari.—This trap, passing into amygdaloid and wacke, and covered with patches of laterite, extends about fourteen and a half miles SE. from Belgaum, a little to the west of the village of Baugwari, though a few narrow slips are crossed a few miles further east. The edge of the trap is seen reposing on the hypogene schists at the base of the trap hills close to the village, the ferruginous quartzites with veins of a diaphanous bluish quartz and hornblende schist, are here seen to basset out in nearly vertical strata.

From the Southern limit of the overlying Trap at Baugwari to the Malpurba.—A few hundred yards to the W. of the village of Hoobly, sixteen and a quarter miles SE. from Belgaum, there is a low hill covered with alluvial soil, in which I found an angular block of quartz with a fibrous structure resembling that of silicified wood, but evidently not of organic origin. The exterior is brown and opaque ;—interior generally translucent, with microscopic longitudinal cavities. Minute longitudinal fibres of talc are discoverable with the aid of a lens, having a parallel direction with those of the fibres of quartz, and I have little doubt that the rock owes its fibrous structure to the presence of talc. I have observed a similar structure in the quartzite associated with the talcose and actinolitic schists of Mysore.

Malpurba River.—About three-quarters of a mile from Hoobly the Malpurba is crossed. It was swollen by the monsoon (July) and unfordable, having about 18 feet of water in the main channel. Rate of surface current, two and a half feet per second. Its breadth, by a trigonometrical observation, ninety-five yards. A tumblerful of the water deposited a scanty sediment of fine red silt, about 1-50th part of its bulk. The temperature of the water a foot below the surface was 74°, of air in shade 72°, of a well 30 feet deep 74° 5′. The temperature of rain-water 73°. (The atmosphere had then been cooled to 70° and 74°, by eighteen days of successive rain, with a pretty steady westerly wind.) The banks of the river are of silt and sand, the left or western bank is steep and high.

From the Malpurba to Darwar.—From the banks of the Malpurba to Darwar, a direct distance of twenty-three miles, the country is hilly and picturesque, particularly around the Mahratta forts and towns of Kittoor and Taigoor, which command a lovely *landscape* of hill and dale. The valleys are generally well watered, cultivated with dry and wet grain, and studded, park-like, with clumps of the Mango and Tamarind, while the sloping sides of the hills, verdant with the rain,

afford a plentiful pasture to flocks of sheep and herds of cattle. The landscape around Darwar partakes of the same character, and was frequently brought to recollection during subsequent wanderings in Karamania, the Troad, and other parts of Asia Minor.

The soil covering the surface of this pleasing tract of country is usually reddish, and the result of the decay and washing of the neighbouring rocks. A few belts of cotton soil appear here and there. The staple products of these soils are rice, yellow and white Juari, Bajra, Raggi, Teimgoni, Till, Tobacco, Saffron, and Maize; *Mimosa*, *Euphorbia*, *Cacti*, *Cassias*, and *Acacias* constitute the majority of the wild vegetation.

The schists forming the hills in the vicinity of Kittoor resemble, petrologically, the jaspideous schists of Bellary and Sondur (described in the Madras Journal for July 1838, pp. 147-49), and consist commonly of chert and brown iron ore, or a ferruginous jaspideous clay in alternate layers; sometimes in straight lines, sometimes in flexures contorted, or bent at acute angles, and resembling those of ribbon jasper. This rock, like that of Sondur, is sometimes magnetic with polarity. It contains nests and cavities lined with blistery and stalactitic hematite, quartz crystals, and veins of smoky quartz. In some places, like the Sondur rock, it puts on the appearance of a breccia consisting of a dark chocolate, or liver-brown paste, highly indurated, giving fire with steel, imbedding angular fragments of the striped ribbon jasper-like variety, and appearing, as Christie justly describes, as if the latter rock had been broken into a number of small angular fragments, which had been afterwards united by the consolidation of the brown variety. I have seen this singular phenomenon most beautifully exhibited in some specimens of a Continental agate breccia in the collection of Mr. Robert Brown, the celebrated botanist, where angular fragments of beautiful jasper and agate are united together in highly transparent quartz. The pieces of agate and jasper must evidently have been once continuous, and re-united on the spot where they were fractured; since, in most instances, the sides of the fractured portions are sharp and angular, and could be refitted into each other with perfect exactness; some are only separated a tenth of an inch by the transparent medium in which they are set. The differently coloured bands identify the fractured portions as having once constituted one integral piece of jasper or agate.

If the reader can imagine a flat piece of ribbon-jasper or agate laid down upon a table, and both broken so that the fractured portions shall not be scattered widely from their neighbours, and a layer of molten glass carefully poured over them, he may form an idea of the appearance of these beautiful breccias. He must not expect, however, to see such regularity in rocks on the large scale.

Towards Darwar the schists pass into chloritic and argillaceous slates and shales, of all shades of white, yellow, red, brown, and green; interstratified with beds of quartz rock, and the jaspideous rock just described, which generally forms crests and mural ridges on the summits of the hills. The latter is often found in irregular masses, obscurely stratified; but, in most cases, as remarked already, in regularly interstratified beds, with the clay and chloritic schists conformable both in dip and direction.

The lustre of this rock is sometimes equal to that of pitchstone, and sometimes dull and earthy; the fracture flat conchoidal in the more compact varieties, splintery and slightly granular in the less compact. The Kittoor and Darwar schists bear evident marks of the alternation produced by the intrusion of granite and trap dikes seen occasionally at the bases of these hills; and, as in the Ceded Districts, and other localities on the hypogene area of Southern India, affords striking illustrations of the correctness of McCulloch's remark on the formation of jasper rock, viz. "where strata of quartz rock, containing much felspar or clay, occur in contact with granite, they pass into jasper if the clay abounds; while in other places they are converted into chert, if less of that earth is present; or, if pure, are rendered perfectly crystalline."*

With regard to the classification of jaspideous rocks associated with the metamorphic schists of Southern India, it is clear they either belong to the jasper rocks, or siliceous schists of McCulloch, both of which, however, I have reason to think, pass occasionally into each other. Both occur in strata among the metamorphic rocks; jasper sometimes forming hills in Siberia and Norway, and it is seen in Scotland and the Appennines imbedded in micaceous and argillaceous schists.

The difficulty that sometimes exists of distinguishing these two rocks has not escaped the notice of McCulloch, who thus remarks: "Jasper presents a few modifications of internal structure which require notice. It sometimes gives indications of a spheroidal concretionary disposition, more or less perfect, and resembling that which, under circumstances of a similar nature, occurs in chert and siliceous schist. In the same way, it sometimes possesses a laminar structure, and in this also it approximates to the siliceous schists. It is easy to see how, from similarity of origin, connexion, and composition, it may be thus a matter of doubt to which of those two rocks any given specimen or bed should be referred. The well-known striped and spotted jaspers owe their appearance to the two structures above mentioned, and occasionally the two are combined in the same specimen."

There is, however, a perhaps somewhat empirical distinction drawn

* Classification of Rocks, pp. 546, 547.

by some geologists between these two classes of rocks, founded upon the supposed less stratified character of jasper, its intrusion into other rocks in the state of veins, and its association with trap rocks, which I will avail myself of to place, *pro tempore*, the jaspideous rocks of Southern India among the siliceous schists, from their, in general, decidedly stratified character, particularly those of the Southern Mahratta Country, which pass into the associated schists, and preserve a conformable dip and direction. The petrographical characters of the Mahratta beds, varying according to the degree of induration, and structure, on the whole, less assimilate those of jasper than in Sondur and other places. The generality of its most jaspideous and laminar beds may be classed in McCulloch's second division of siliceous chert, viz.—

"*F.* Laminar, with alternate colours, and forming varieties of the striped jasper of mineralogists. The colours are commonly shades of red, brown, yellow, and purplish black, and these kinds appear to be derived from the coloured shales.

"*G.* Containing imbedded crystals of quartz, and of a porphyritic aspect."

The physical aspect of the country to the W. and SW. of Darwar is hilly. The elevations are generally, like those of the clay slate of the Cambrian group, round-backed, smooth, of no great altitude, and separated by well-cultivated valleys, or narrow ravines. They are partially covered with a low shrubby vegetation, principally of *Mimosa*, *Cacti*, and the *Cassia auriculata*. To the east stretches the great plateau of the South Mahratta Country and Ceded Districts, covered for the most part with a thick layer of *regur*, and continuing, with but few hilly interruptions, across the Peninsula to the Eastern Ghàts. The soil in the immediate vicinity of Darwar is reddish and clayey, evidently the alluvium of the schistose hills, and disintegration of rocks *in situ*.

The rocks composing the hills are schists passing into slates and shales (agreeably to Lyell's distinctions of these terms). The general structure is perhaps more schistose and shaly than slaty. The structure varies from massive and obscurely slaty to finely laminar, and from compact and flinty to soft and sectile. The laminæ are nearly vertical, and generally run parallel with the prevailing line of elevation, viz. NW. and SE. The stratification, if not identical with the lamination, is obscure. It is well known, however, that the lines of fissility in slates are not necessarily those of stratification, the former being often caused by the arrangement of mica, chlorite, or talc; petrographically speaking, the rock passes from a green chloritic schist into all shades of white, yellow, red, and brown, sometimes singularly arranged in stripes, in contorted and waving bands; red and white being the

prevalent tints. Felspar, in a clayey slate of disintegration, is the prevalent mineral, blended with quartz and tinged with iron. The white varieties seldom contain silex sufficient to give them the character of *Kaolin.* The whole mass is sometimes reticulated by veins of a brown ferruginous quartz and impure iron ore (often split in the centre, and the sides of the fissure lined with quartz crystals), having apparently no decided direction. Iron pyrites are seen in the chloritic schists; this rock, particularly in the vicinity of trap dikes, has a tendency to the prismatic and rhomboidal forms, in which the lamination, though generally obscure, is sometimes still distinctly traceable. A system of joints, running nearly at right angles with those of lamination, often intersects the whole group of these schists. These jointed portions are not capable of that indefinite subdivision into similar solids by which Professor Sedgwick justly observes the true cleavage planes may generally be distinguished from the joints. The difficulty in the schists of the South Mahratta Country is to discriminate between the planes of cleavage and those of mechanical deposition, or chemical precipitation, for which there are three good tests, viz. the interstratification of another bed of rock, the coloured bands of successive deposition, and a peculiar but slightly dimpled appearance on the surfaces of the planes never seen on those of cleavage. From the occurrence of the latter on the planes of the laminæ of the Darwar rocks, and from the iron and dip of the large interstratified beds of quartz and siliceous schists, I am inclined to consider that the true lines of stratification run nearly parallel with that of elevation, viz. nearly NW. and SE., and that the laminæ are those of deposition; while the microscopic fissures by which the rock is cleft into rhomboidal and prismatic forms may be received as those of true cleavage.

My friend Captain Allardyce, who has minutely examined the rocks about Darwar, writes me that the direction of the laminæ and that of stratification keep very constant to one point of the compass, viz. NW. by N., for a great distance, perhaps over an area of from fifty to one hundred miles. One may pick up a fragment of chlorite slate of a triangular, pyramidal outline, the external planes of which will be ferruginous, while the interior is divided into minute laminæ *not* ferruginous, and coincident with only one of the planes. On examination of the rock *in situ*, this minute lamination is found to be vertical, and invariably divided NW. by N., conformable, in short, to the line of elevation. The chloritic schist N. of Darwar is of a bluish-green tinge, greasy to the touch, and sometimes so massive in structure as to make an excellent building stone, although it rarely loses its slaty fracture. Thin pieces, *per se*, before the blow-pipe, fuse partially on the edges into globules of a greenish-coloured enamel.

It is often intersected by ferruginous quartz veins, or rather layers, that, penetrating the lateral joint seams, and the almost vertical layers of stratification, divide the rock into cuboidal masses. Veins of a reddish grey or white kunker, both friable and compact, occur.

Country South of Darwar to the Mysore and Canara Frontiers.—From the hills of Darwar to the Mysore frontier near Bunwassi and Chundergooty, the face of the country presents a plain diversified with a few mammiform and smooth conoidal truncated hills, which do not rise to any considerable height. The soil is generally reddish and alluvial, crossed in an easterly direction by narrow belts of cotton soil. The formation is much the same as at Darwar. Dikes of greenstone and beds of kunker now become more frequent. A large deposit of the latter is crossed on the road between the old town of Hoobly and the German Mission House, about fifteen miles SE. from Darwar. The wells near are often brackish, and so deep as 70 feet. Both Hingari and Mungari crops are cultivated. Rice, too, is grown in some of the moist, shallow valleys and flats below the small tanks, which now become more numerous.

Bunwassi and Mysore Frontier.—Towards Bunwassi quartz rock prevails with greenstone dikes, having a general easterly direction, often covered by beds of laterite and lateritic conglomerate, imbedding fragments of quartz rock in a cellular brown ferruginous paste. This rock has been employed in the construction of the wall enclosing the quadrangle of the ancient temple and the old temple at Bunwassi. A little farther south rises from the schists the lofty rock of Chundergooty in Mysore, a mountain mass of granitoidal gneiss divided by vertical and almost horizontal fissures.

From Bunwassi to Gudduck.—From Bunwassi, ENE. to Savanoor, the chloritic and coloured schists and slate clays continue. Near the latter place dikes of greenstone become more frequent, accompanied by depositions of *kunker*, which is seen filling fissures in the schists, and overspreading their surface beneath the alluvial soil. The direction of the beds at Savanoor suffers a deflection after leaving Darwar of about 40°, being nearly due N. and S., dipping at an angle of about 40° towards the east. They terminate on the NE. between Savanoor and Gudduck, close to Lackmaisir. Here a spur from the principal N. and S. line of elevation runs nearly E. and W., dipping towards the S.; several similar spurs are crossed between Bunwassi and Lackmaisir; the dikes of greenstone run in a similar direction. The schists, in the vicinity of the dikes, are indurated, siliceous, and often abound with iron. Crystals of liver and brass-coloured iron pyrites are scattered through its structure; cotton soil alternates in these strips with the red clayey alluvial soil. It was first observed W. of

Bankassur, near which the vegetation peculiar to the Western Ghâts terminates rather abruptly.

At Lackmaisir gneiss is seen on the bank of a nulla running nearly E. and W. with a dip of 35° towards the S., and further N. it rises into a low round-backed ridge. Proceeding still more N. granite occurs in low bosses and detached blocks, and rises into a few clusters at the town of Kul Mulgoond. Near Hurti, on the S. flank of the Kupputgode Range, resting on the gneiss, is a hill of mammiform shape, having its surface covered with detached, angular, and rugged masses of a calcareous rock, which appear to have been subjected to the action of violent disruptive forces. It is very liable to be mistaken, from the colour, hardness, and granular texture, for a variety of the massive chlorite schist we have just left behind ; and in some hand specimens it resembles diallage and serpentine. The mass of it, however, on the application of a lens, clearly exhibits its true aggregate character : it is composed of minute angular fragments of a dark glistening quartz, and crystals of a pale flesh-coloured felspar, cemented by a greenish, granular subcrystalline paste, composed principally of carbonate of lime, and containing disseminated scales of mica. The application of dilute nitric acid to the rock excited but a feeble effervescence ; but from the powder the extraction of carbonic acid gas was abundantly evident. Like the chlorite slate, it imbeds cubical, brass, and liver-coloured iron pyrites. Before the blow-pipe, *per se*, it phosphoresces slightly, and exhibits, on thin edges, shining points of black enamel. The compact varieties of this rock are susceptible of a high polish, and are used for ornamental architecture. Some of the finely polished slabs in the elaborately sculptured mosque in the town of Lackmaisir appear to be of this stone, retaining, like *lapis lazuli*, the pyrites which shine like so many spots of gold in its polished surface. In weathered surfaces of the rock these crystals are often seen projecting. It is not unlike some varieties of the celebrated calcareous *breccia di verde* of Egypt.

From its massive character and want of a proper section, I could not find whether it was interstratified with the gneiss, or rested unconformably upon it. Gold dust is found in the Nalas of Hurti, of Soltoor, and of Chick Mulgoond.

Beyond this singular hill runs a dike of greenstone E. by S., which is crossed on the road, and also a range of chlorite and clay slate hills crested with ferruginous siliceous schist, having a similar direction. Passing this, the country slopes northerly to Gudduck, where gneiss and felspar rocks continue.

From Gudduck E. to the Ceded Districts, and N. to Gujunder Ghur.— From Gudduck easterly to the Tumbuddra and the Ceded Districts, the formations consist of gneiss, hornblende slate, and granite; and

from Gudduck westerly to Darwar, first, gneiss and hornblende slate; succeeded, about seventy or eighty miles E. of Darwar, by chlorite and coloured schists and shales. North of Gudduck the hypogene schists and granite extend to Gujunder Ghur, where they are covered by the sandstone beds.

Kupputgode Hills.—The Kupputgode range presents an example of one of the crop dislocations which traverse the table-land of the Peninsula in a direction from E. by S. to ESE., often influencing the courses of the large rivers which, rising in the Western Ghàts, flow over the table-lands through gaps in the Eastern Ghàts to the Bay of Bengal. It commences a little south of Gudduck, and proceeds in a curvilinear direction easterly, until a little W. of the village of Kuddumpore, where it bifurcates the principal branch, taking a S. 25° E. direction to the Tumbuddra, which flows through a wide gap, and is continued into the Ceded Districts by Harponhully. The northern branch pursues an easterly course towards Dummul, where it traverses a wide plain extending as far as the eye can reach to the NE. The strata dip near Gudduck towards the N. at an angle of 35°. Those of the southern chain, below the bifurcation and change in the direction, dip E. 20° N.; direction of strata S. 20° E. The dip frequently varies with the flexures and contortions into which the hypogene schists have been thrown. In one of the highest peaks it appeared *quâ quâ versal;* and near the temple to Kupput Iswara, whence the range derives its name, I found the dip to the SW.

An immense dike of basaltic greenstone emerges from the base of the strata near the point where the range suddenly bifurcates, accompanied, as usual, by large deposits of *kunker*, which fill most of the seams and fissures in it and the adjacent rock. Considerable tendency to silicification is observed; the schists are profusely veined with quartz of different hues, white, pinkish, and diaphanous blue, reddish, smoky, and black; seams and large veins of basanite also occur.

The Kupput hills are principally composed of hornblende and chloritic schists, gneiss, and mica slate; large interstratified beds of siliceous and ferruginous schists, as at Darwar, often forming thin ridges; seams and thin beds of a crystalline white marble occur, which, near their junction with the hornblende slate, are often coloured green. On the flanks of the range, at the base, gneiss, invaded by granite, is seen, both quartzose and felspathic, containing rose-coloured quartz and felspar. Near Dummul the gneiss is often so much weathered as to resemble sandstone; schorl and actinolite are usually seen in the quartz veins, which intersect it. The dip of the gneiss is nearly vertical at Dummul, in other situations it varies almost to horizontal; some of the hills are capped with laterite, resembling that of Sondoor. The beds of the

Dhoni rivulet, which has its rise in these hills, contain gravel and sand, in which gold dust is found associated with magnetic iron sand, menaccanite, iron ore, grains of platinum, grey carbonate of silver, grey carbonate of copper, &c. Manganese is also found in considerable quantities. Tippoo excavated pits for gun-flints, of which I have given a description elsewhere.* Potstone occurs with the talc schist in this vicinity, and is used by the natives in sculpture, for cooking vessels, and for giving a smooth surface. The occurrence of gold, silver, copper, platinum, and manganese seems to have escaped the observation of Christie, Marshal, and other writers on the South Mahratta Country ; and there doubtless exist many other minerals in its rocks now unknown, but which the researches of other and abler pioneers than myself, and with more leisure, will not fail to elicit.

Geographical Position and Extent of the various Rocks of the South Mahratta Country.

Hypogene Rocks.—Commencing on the south, we find the greater portion of our area occupied by hypogene schists and argillaceous shales and slates, reaching on the north from Gujunder Ghur from the edges of the limestone and sandstone tracts ; and at Baugwari, fifteen miles SE. from Belgaum, basseting from beneath the overlying trap, whence they extend by Darwar and Kittoor, forming the base of the Western Ghàts, and underlying the laterite of North Canara to the sea on the west, stretching into Mysore on the south, and into the great plains of the Ceded Districts and Hyderabad on the east.

Near the NW. angle they are seen outcropping from the sandstones near Gokauk as a *salbande* at the edges of the overlying trap formation along the N. bank of the Kistnah, in narrow zones along the western base of the Sitadonga hills. They are seen with granitic rocks on the summit of the Ram Ghàt, and below it hornblende schist occurs on the sea shore at Vingorla.

Extent of the Limestone and Sandstone Beds.

The Limestone.—The southern boundary of the limestone and its associated shales has not been traced with accuracy, but we find it four or five miles S. of Kulladghi.

On the north-eastern extremity it emerges from the overlying trap near Talicotta, is capped by sandstone at Mudibhal, but reappears in the valley of the Kistnah at Chimlaghi. A little to the SW. it is again overlain by the great mass of sandstone forming the Sitadonga hills, but again is seen forming for the most part the base of the great plains of Kulladghi and Bagulcotta, and stretching to the west to the sand-

* Madras Journal of Literature and Science for January 1840, p. 42.

stone ranges of Gokauk and Padshahpoor which bound it to the west, while the northern edge is fringed irregularly along the banks of the Gutpurba by the overlying trap.

Extent of the Sandstone.—The sandstone and conglomerate ranges usually skirt the great limestone plains as the sand and gravel shores environ the bed of some dried-up inland sea, and this appearance is heightened by the bold, flat-topped headlands and receding bays presented by the sandstone ranges in their curvilinear outline. This continuity of these long horizontal ranges, which usually preserve an uniformity of height, rarely exceeding 300 feet, has, however, been greatly violated by, apparently, denudatory aqueous causes; and it is not uncommon to see outlying masses and short ranges of sandstone at considerable distances from the principal deposit, for instance, the detached rocks of Noulgoond, Pedda, and Chick Nurgoond (where it occurs in scarped masses cropping granite and the hypogene schists), and the detached central range between Kulladghi and Gokauk.

The Sitadonga hills form the eastern fringe to the district, and those of Gokauk the western, extending southerly from its northern limits on both sides of the limestone plain of Kulladghi and Bagulcotta to about the latitude of the Malpurba river. The subjacent limestone thins out, or is entirely wanting at the edges, where the sandstone is often seen resting immediately on the granite and hypogene schists. The eastern ridge of sandstone turns westerly near Gujunder Ghur.

Extent of the Laterite.—Laterite is seen capping some of the sandstone hills of the Sitadonga range, and a narrow belt along its eastern flank. It also occurs in the form of low hills and patches overlying the limestone in the plains of Bagulcotta and Kulladghi.

In the southern parts of the district it occurs in a few patches covering the hypogene schists of the Kupputgode range, and on the summits of the Ghàt ranges west of Belgaum and Darwar.

Extent of Kunker.—Kunker is pretty generally distributed; there are beds near Badami and Hoobly, of some extent, covered by alluvium.

Extent of the Regur.—This remarkable soil, or deposit, for so I consider it, resembles much the *Tchornoi Zem* covering the steppes of Russia; it prevails almost exclusively in the plains east of Darwar, and those of Kulladghi and Bagulcotta, except where interrupted by chains of hills, and covered by the alluvium washed from their sides, in beds from a a few inches to 30 or 40 feet deep.

Extent of Plutonic and Trappean Rocks.—Plutonic rocks are rarely seen developed in any extent on the surface of the South Mahratta Country, but their effects are sufficiently apparent in the altered state of many of the lower rocks.

Granite is seen in bosses and rocks near Lackmaisir, at Gujunder

Ghur and Noulgoond, underlying the sandstone at Mulgoond, in the gneiss of the Kupputgode hills, at Gudduk and Dummul, and in the districts bordering on the Tumbuddra and east of Gujunder Ghur.

The largest dikes of basaltic greenstone, which I observed, were at the west base of the Sitadonga hills, and in the Kupputgode range.

Extent, &c. of overlying Trap.—The southern margin of the great sheet of overlying trap, which overspreads almost the whole of Central and Western India and the Concan, runs across the northern part of the South Mahratta Country, covering all rocks except the laterite, kunker and regur, all which overlie it; entering from the Nizam's territories by Firozabad on the Bhima, it descends to the Kistnah near Churilaghi, near its confluence with the Gutpurba, and follows, with some irregularities, the northern bank of the latter river by Kotabangy, a little to the north of the falls of Gokauk to the Western Ghàts and the sea, which it reaches a little north of Malwan.

The narrow zone of oliviniferous trap, crossed between the falls and Koonoor, possibly connects the outlier of this rock on which Belgaum stands with the main *coulée.*

North of the Kistnah the trap spreads over the Kolapoor, Sattarah, and Poonah countries; to the NE. it covers the plains of Bijapore and the Nizam's territories, stretching towards Gwalior. Where the trap terminates to the west of Belgaum is not exactly ascertained, as the summits of the Ghàts near the Pass down to Vingorla are composed of granite and the hypogene schists; but the river Gutpurba, as has been observed already, brings down a few calcedonies to the falls of Gokauk. The amygdaloid noticed at Baugwari, and in the vicinity of Belgaum, appears to have escaped the observation of Christie, who states he has not seen this rock *in situ.*

Classification of the Rocks of the South Mahratta Country.

Christie, partly adopting the Wernerian system, has classed the rocks of the South Mahratta Country under five heads, viz.—

1st.—Granite.
2nd.—Transition Rocks.
3rd.—Old Red Sandstone.
4th.—Secondary Trap.
5th.—Alluvial.

Under the head of Transition he has included the gneiss and talc schist of Dummul, Nurgoond, and Gairsuppa, the chlorite and clay slates, siliceous schists and quartzite of Darwar, Kittore, and, in short, the schists of the whole of the central and southern parts of the Darwar districts, together with the limestone of Kulladghi and Bagulcotta.

Some clay slates associated with these limestones he has classed among the grauwacke group, and the sandstone with the old red sandstone.

This classification has been apparently grounded on mineral resemblance of the schists to the transition rocks of Werner, their in general highly inclined strata, and on the circumstance of the sandstone resting, in some localities, on the schists in unconformable and almost horizontal stratification. These facts, without the additional evidence of organic remains, and in the total absence of any associated stratum the age of which has been distinctly ascertained, would hardly be deemed, by geologists of the present day, sufficiently conclusive to warrant the rocks of the South Mahratta Country being referred to the same epochs as the transition, grauwacke, and old red sandstone rocks of Europe, as now defined.

Werner, in his improvement of the system of Lehman, who divided rocks into three classes, viz.—

1st.—Primitive: comprising plutonic or granitic rocks, and the hypogene or metamorphic schists formed with the world, and containing no fragments of other rocks;

2nd.—Secondary: including the aqueous and fossiliferous strata which resulted from the partial *débris* of the primitive rocks by a general revolution;

3rd.—Alluvial: comprehending the *débris* of local floods and of the Deluge of Noah;

—intercalated a 4th class between the 1st and 2nd class; and under this head he placed a series of strata, which he thought formed a passage between Lehman's primitive and secondary rocks, hence called transition, assimilating, on the one hand, to the crystalline structure of mica and clay slates, and, on the other, evincing traces of a mechanical origin and organic remains. These beds were chiefly of clay slate, arenaceous rock, coralline and shelly limestone, and grauwacke a grey argillaceous sandstone, often schistose, imbedding small fragments of quartz, flinty slate, or basanite, and clay slate, cemented together by argillaceous matter. Werner, in the confined space that fell under his observation, found both the primitive and transition schists highly inclined, while the newer aqueous or secondary beds were horizontal; hence his too hasty generalisations. It is now ascertained that secondary strata and green tertiary beds are often found in nearly vertical position, and that some granites are newer than the lias and chalk; on the other hand, gneiss is often seen in horizontal beds, and Mr. Murchison has lately discovered in Russia the older stratified rocks extending in horizontal unbroken masses for the distance of nearly one thousand miles. The value of mineral character, unsupported by others,

is of small value as a test of the relative ages of stratified rocks; we see lacustrine strata of the Eocene period identical in all their mineral characters with the secondary new red sandstone and its associated marls, and certain arenaceous beds in the cretaceous formations of the Alps, and even in some tertiary deposits, which can hardly be petrologically distinguished from the rocks of the grauwacke group.

Although it is quite possible that future discoveries may prove the sandstone to be equivalent to the old-red, and many of the rocks, classed as transition, really to belong to that period, yet I consider it preferable, for the present, to arrange the rocks of the Southern Mahratta Country agreeably to the acknowledged geological evidence they themselves exhibit, in addition to that of a mineral character, viz. superposition, imbedded fragments of older rocks, intrusion with or without alteration, conformable or non-conformable stratification, and this with little reference to European formations. The classification will therefore, for the most part, be that of relative age. Not a single organic remain, I may observe, has hitherto been discovered in the most recent deposit in the Southern Mahratta Country to assist us to any conclusion, except recent terrestrial and fresh-water shells in the newer kunker.

The stratified rocks will be classed in the ascending order, commencing with the hypogene, or lowest series; the plutonic and trappean rocks will succeed.

Age of Hypogene Rocks.—The hypogene schists are evidently the lowest in the group of normal rocks, and have suffered the greatest disturbance, as already observed. The lowest member in this series is usually gneiss, and the highest either marble or clay slate; but there are many exceptions to this remark.

Age of Limestone.—Christie has classed with the hypogene schists under transition, the limestones of Kulladghi and Bagulcotta; but from extensive observation of this rock, here and in other parts of India, I am inclined to think it, with its associated slates and shales, of more recent origin, principally from its resting on the gneiss, &c. in usually unconformable stratification, often dipping but a few degrees over large tracts, and its more intimate association with the sandstone which caps it; these rocks being usually seen together. The limestone is inclined near Kulladghi at an angle of 25°, but this disturbance is confined to areas of small extent, speedily recovering its usual little inclined position. In some localities, as near Ryelcherro and Juldioogum in the Ceded Districts, it is seen to alternate with the sandstone. Traces of coal have been discovered in a limestone in the Hyderabad country, which appears identical with the Kurnool and Kulladghi limestones.

Sandstone.—The sandstone, though sometimes alternating, and often in conformable strata, with the limestone, is on the whole less disturbed,

as just observed; and generally appears in almost horizontal strata, particularly in the hills south of the Malpurba. On the north bank of this river the sandstone beds have suffered more disturbance, and Christie observed them dipping at an angle of 40° to the NW. at Chick Nurgoond, resting on vertical hypogene schists (talc slate). In the NE. portion of the district the sandstone of the Sitadonga hills rests on vertical chlorite and siliceous schists, with a dip towards the NE. varying from 5° to 28°. In the NW. portion, near Gokauk, the stratification is obscure, the beds appearing as thick and nearly horizontal tabular masses. Where the strata are horizontal, the hills which they compose run in long, low, flat-topped, wall-like ridges, terminating, like trap elevations, rather abruptly, and their sides often presenting mural precipices. These ranges usually run in corresponding elevations, averaging about 200 feet from the surface of the plain. The maximum thickness of the deposit, perhaps, does not exceed 400 feet.

From their being sometimes in unconformable stratification with the limestone, and imbedding fragments of its cherts, it might be inferred that an interval of plutonic disturbance took place between the periods of their deposition; though we have not as yet sufficient evidence to refer them to two distinct geological epochs. Basanite, quartz, hornblende, actinolite, and other of the hardest fragments of the hypogene and granitic rocks, are occasionally seen in the sandstone, but rarely pieces of gneiss or of the granite mass itself,—a circumstance indicating great trituration of its components prior to consolidation. With regard to mineral character, the limestones and sandstones of the South Mahratta Country resemble those of the Devonian group, perhaps, more than any other; but it has been already remarked what little reliance is to be placed on this test of the age when unsupported by other evidence, more particularly as organic remains have been discovered in the sandstones of Hyderabad and Nagpore, supposed to be identical with those of the Southern Mahratta Country, which would indicate a more recent era. These fossils are a hollow compressed body, of a deep black colour and compact structure, the centre of which is filled with sandstone, and supposed to be a vegetable by Mr. Malcolmson, who discovered it in the sandstone hill of Won. The others, from the sandstone in the vicinity of Nagpore, were discovered by Lieut. Munro, H. M.'s 36th, and are impressions of plants which resemble the Glossopteris Danœoides of the Burdwan coal field, as figured by Royle. With these plants impressions were found, which Mr. Malcolmson conceives to be not unlike those of the large bony scales of the sauroid fish of the carboniferous and old red sandstone rocks, especially those of the latter. Mr. Malcolmson showed me these specimens at Bombay, and I agree with him that these last impressions were too imperfect to justify any

opinion as to their real nature. As he justly remarks, in a subject so new, and I may add as likely to afford so important a key to the classification of the rocks of India with those of Europe, no indication should be overlooked. The occurrence of a Glossopteris in strata imbedding organic remains of the Devonian group would be novel and interesting.

I am not aware that the diamond, a marked mineral characteristic of the sandstones of the Ceded Districts, occurs in the Eastern Ghâts from the Pennaur to north of the Kistnah, and which—as far as a peculiar mineral characteristic can perhaps identify rocks, identifies it with the diamond sandstones of Nagpore, in which the fossils alluded to as discovered by Mr. Munro occur, and those of Punnah in Bundlecund—has hitherto been discovered in the sandstone of the South Mahratta Country. A bed of anthracite, 3 feet broad and 200 feet long, has lately been discovered in the sandstone of the Goond country, and traces of it exist in the sandstone NW. of Nagpore.

Laterite.—Next in order of superposition to the sandstone comes the overlying trap; but, adopting the arrangement of Lyell, I shall place it and the granitic rocks apart from those that have a confessedly bedded structure.

Laterite was classed both by Voysey and Christie with the overlying trap; by the former as a volcanic rock. Christie has not given an opinion as to its origin. It has been thought of volcanic origin, principally from its apparently unstratified and non-fossiliferous character, and being frequently associated with trap rocks. It, however, occasionally possesses a distinctly stratified and conglomerate character, and passes into a loose coarse sandstone, as at Pondicherry, imbedding silicified wood; and at Beypoor, on the Malabar Coast, it passes into a loose sandstone, imbedding layers of lignite. General Cullen was the first to discover lignite and carbonized seeds in the laterite of Quilon and Travancore. He now writes me, that he has discovered extensive beds of lignite in the laterite formation of these provinces.

Some geologists suppose it is the result of the weathering, still in progress, of granitic and trap rocks *in situ*. The fact of its imbedding rolled fragments of sandstone when resting on granite, and the beds of lignite and silicified wood it contains, militate strongly against this theory; and, independently of these facts, nothing is more common in lateritic tracts than to see a hill of trap or of hornblende, gneiss, or other hypogene schists capped with a thick bed of laterite, while the adjacent hill, composed of an exactly similar rock, and equally exposed to the action of the weather, is quite bare of laterite. I have examined beds of laterite resting on trap and amygdaloid imbedding calcedonies and jasper, but have not hitherto detected in the former any fragments

of these tough siliceous minerals, which are found to resist successfully even the attrition of the most rapid streams of India, long after the imbedding trap has disappeared and been lost in alluvial sands, and carried across the Peninsula into the bed of the ocean.

Their occurrence, however, particularly at the point of contact, would not prove that the laterite was formed from the upper portions of the subjacent trap weathered *in situ*. A detrital and mechanical origin like that of the sandstone would carry into it the harder unweathered nodules of the rocks from which it was derived. I have also seen laterite resting on limestone without a traceable particle of lime in its composition. This could not have been limestone weathered *in situ*.

The fact of one hill being capped with laterite, and its neighbour being left bare, is a circumstance also militating against another theory adopted by some Indian geologists, viz. that of its alluvial origin from causes now existing. It is impossible to see the laterite capping in tabular strata, as at Beder, hills of trappean or hypogene rocks separated by valleys, wide plains, or elevations, in which nothing but the latter rocks are seen, without coming to the conclusion that the beds of laterite were once continuous over these spaces, and stripped off by waters of which nothing but the trace of denudation now remains. Natural sections often remind one forcibly of that striking instance of denudation of the red sandstone, on the north-west coast of Ross-shire, given by McCulloch in his Western Isles, vol. ii. p. 93, pl. 31, fig. 4.

The annexed diagram is a section taken on the western coast, between Honawer and Sedashegur.

The rarely fossiliferous character of this iron clay, or ferruginous clay, as it has been called, which has puzzled some geologists, and inclined others to the theory of its volcanic origin, may be in some measure attributed to its highly ferriferous nature, often approaching that of an ore of iron. It is a fact, and, as Lyell observes (Geol. vol. ii. p. 102), one not yet accounted for, that scarcely any fossil remains are preserved in stratified rocks in which this oxide of iron (derived from the disintegration of hornblende or mica) abounds; and when we find fossils in the new or old red sandstone in England, it is in the grey and usually calcareous beds that they occur.

I have often observed, particularly in the Western Ghàts, and on the Malabar and Concan coasts, where the rains fall heaviest, that the granitic, hypogene, and trappean rocks containing most iron, weather into ferruginous and coloured clays, that sometimes, lithologically speaking, resemble laterite, and these, when that rock is near, cause the appearance of their passing into it. I have also observed beds of considerable magnitude of an impure oxide of iron in gneiss and hornblende,

sometimes cellular and pisiform (and from whieh much of the iron in laterite has doubtless been derived); but when we look up from the mieroscopic view afforded by these slowly weathering bloeks of rock and beds of ore *in situ*, and cast our eyes upon even the present extent of laterite over the surfaee of Southern India, the thickness of its beds (at Beder 200 feet), its flat-topped ranges of hills, the great gaps effected in their continuity evidently by aqueous eauses no longer in aetion, its often elevated position above the drainage of the country, its imbedding layers of lignite from silicified wood, and oceasionally water-worn pebbles of distant roeks, we find we can no more attribute its origin to the weathering of rocks *in situ*, or to their present transported detritus, than that of the old sandstones of Europe to the sandy disintegration, now in progress of aeeumulating by rains, around the bases of older sandstone, granite, and hypogene roeks, although a mineral resemblanee exists, as in the ease of the true and pseudo-laterites.

Having said thus much to warrant my placing laterite among the rocks of aqueous and mechanical origin, I shall proeeed to notice it as it occurs in the South Mahratta Country. It may be remarked, *passim*, that fossil shells have been scarcely ever found in the tertiary Rhenish brown eoal beds, though in the vicinity of Bonn large bloeks have been met with of a white opaque ehert, eontaining numerous casts of fresh-water shells, which appear to belong to *Planorbis rotundatus* and *Limnea longiscata*.* The laterite, capping the overlying trap of the South Mahratta Country, does not appear to have been invaded or altered by it like the brown coal beds. But similar blocks of ehert, containing fresh-water shells, viz. two speeies of Cypris, three of Unio, and many individuals referable to the genera Paludina, Physa, and Limnea, and also Gyrogonites, have been discovered by Mr. Malcolmson and myself entangled in it.

Near Kulladghi, where it reposes on the limestone, it exhibits undoubted signs of horizontal stratification. It is never seen altered by the granite or trap. West of Kulladghi, near Ooperhutty, beds of a gritty sandstone, loosely agglutinated, resembling that into which the laterite passes near Beypoor on the Malabar Coast, rest in a similarly horizontal and unaltered position on the overlying trap, fragments of which occur in this superimposed sandstone.

Kunker, Gravel, and Regur.—That singular deposit, for so I eonsider the regur, is superimposed on all the roeks that I have just described. There is frequently an intervening bed of gravel or of the older kunker, in whieh the remains of a mastodon have been diseovered, near Hingoli (Nizam's country). I have not met with gravel beds in the South

* Lyell, Elements, vol. ii. pp. 281, 282.

Mahratta Country. The diamond is found in the gravel beds below the regur in the Cuddapah district. My ideas regarding the origin of those deposits have been elsewhere stated.

Age of the Plutonic and Trappean Rocks. Granite.—From the rarity of sections, it is difficult to ascertain the relative age of the granite by the tests usually resorted to by geologists in fixing the ages of plutonic rock, viz.:—

1*st.*—Intrusion and alteration.
2*nd.*—Included fragments.
3*rd.*—Relative position.
4*th.*—Mineral character.

Christie evidently views the granite of the South Mahratta Country as primitive, according to the Wernerian theory; but states that there is a granite at Gairsuppa, in Canara, "not so old as the common granite of India," which, from mineral character and association with the gneiss and other hypogene rocks, he classes with them, in the transition series of this school. But within the last half century it has been ascertained that this granite, considered formerly as the oldest of rocks, sometimes belongs even to the tertiary period, and its presence at Gairsuppa, and in the southern portions of the South Mahratta Country, intruding into, disturbing, and altering, as it does, these crystalline schists, plainly proves its posterior origin.

But there is no proof adduced of any other granite of India being anterior to the granite of Gairsuppa, and there is every reason to believe that the granite of Gairsuppa and the Western Ghàts must rank among the oldest granites of India, until the age of the rocks they have altered and intruded into be satisfactorily proved to be posterior to the other hypogene rocks that prevail so extensively over its surface.

There is, moreover, a granite more modern than the common granite of the Western Ghàts, Gairsuppa, and indeed of India, which is seen to penetrate the latter in veins and dikes,—a fact proving its posterior origin,—and which, although it has not hitherto been discovered in the state of dikes in the sandstone and limestone, has converted the former into quartz rock, and the shales of the latter into jasper and chert, indicating a posterior or contemporaneous origin.

The disturbance and metamorphic effects produced by the eruption of this granite do not appear to extend to any great distance from the foci of plutonic disturbance. The sandstone ranges in the South Mahratta Country are usually little inclined, particularly in the ranges south of the Malpurba, resting unconformably on the hypogene schists and granite, in highly inclined stratification; but, travelling a short distance north, we find them showing more signs of plutonic disturbance, and, according to Christie, the sandstone of Chick Nurgoond is uplifted at

an angle of 40° resting on the vertical hypogene schists ; a fact indicating two eras of plutonic disturbance.

It is a striking fact that no fragments of undoubted granite or gneiss have been noticed in the pebbles of these sandstone conglomerates, which consist chiefly of quartz, chert, jasper, basalt, flinty slate, and the hard portions of the chloritic and actinolitic schists, the two last rocks bearing a small percentage in relation to the rest, and those of quartz greatly predominating in the lower beds. The inference is, either that the attrition, which converted the wreck of the pre-existing rocks into sand and gravel, was so great as to grind down their mass beyond the possibility of recognition, leaving nothing but fragments of their hardest nodules and veins, or that the oldest granite was still undenuded, and, with the gneiss at this era, was as yet but partially uplifted, and retained its natural subordinate position.

It is certain, however, from the included pebbles of the flinty slate, jasper, actinolitic and chloritic schists, that the plutonic action of granite had commenced prior to the origin of the sandstone, and had metamorphosed or crystallized the hypogene, or rather formed schists of the wreck of which the sandstone is formed.

If this reasoning be admitted, it is obvious that at least two epochs of great plutonic activity have taken place. The first anterior to the formation of the limestone and sandstone, by which the hypogene schists were rendered crystalline and partially subverted. The second, posterior ; and marked by another granitic eruption, which burst up through fissures in the old granite, altering the limestone and sandstone. From the latter occasionally resting on the former in less disturbed strata, it may be inferred that the limestone suffered some degree of dislocation before the sandstone was deposited. There is little doubt, from the unaltered and highly inclined stratification of some of the beds resting on the granite, that it must have been protruded by this second upheaval in a solid form. Other highly inclined beds are altered, which indicates a heated but solid state of the intruding rocks.

The third movement, or series of movements, by which perhaps a great part of Southern India was slowly and gently lifted up to its present elevation, raising beds of laterite in a horizontal position to the height of 7,000 feet and upwards, appears to have taken place during the tertiary period. This great *soulvement* is perhaps rather attributable to volcanic than plutonic action, since the granites of both eras appear to have been raised in a solid form, and no granite of India has yet been observed altering or intruding into tertiary rock. Possibly its phenomena were connected with those attending and following the grandest eruption of trap in the whole world, the overlying trap of Western and Central India, which evidently took place in the tertiary period.

During these epochs, it is almost needless to say that the surface must have undergone various oscillations at different periods, during which the aqueous strata were deposited, consolidated, and partially denuded, uplifted, and submerged.

Age of Basaltic Greenstone.—Like the granite, the basaltic greenstone is evidently of two eruptive epochs, as we see dikes of it crossed by more recent dikes.

The greenstone of the first epoch is posterior to the older granite and hypogene rocks which it penetrates, and with which it has been uplifted in a solid form; partaking of all their dislocations and abrupt truncations. This older greenstone stops short of the sandstone; the conglomerates of the latter imbed pebbles of the greenstone.

The newer basaltic greenstone penetrates and alters the limestone and sandstone, but stops short of the laterite. Both rocks are distinguished mineralogically from the tertiary or overlying traps by their rarely assuming an amygdaloidal character, and their freedom from agates, opals, calcedonies, zeolites, green earth, olivine, &c., so abundant in the latter.

Age of the overlying Trap.—It overlies and penetrates the sandstone and newer basaltic greenstone, and from its altering and disturbing the fresh-water limestones of Nirmul, and its superior position to all the rocks of the South Mahratta Country, except the laterite, kunker, and regur, is referred to the tertiary epoch. It is strikingly, mineralogically, distinguished from the older trap rocks, as just explained.

The order of superposition of the rocks of the South Mahratta Country, in descending, appears to be as follows :—

Rocks	Group
Regur, Old kunker, Laterite, Lateritic sandstone, Overlying trap,	1st group.
Basaltic greenstone, Granite, Sandstone,	2nd group.
Basaltic greenstone, Granite, Hypogene schists,	3rd group.

Comparison of these Groups with classified European Groups.—There can be little doubt of the rocks of the first group belonging to the tertiary period, after what has been remarked regarding the age of the overlying trap on which they are superimposed. The remains of the Mastodon have been found, with other fossils pointing to the Pleiocene division of the tertiary epoch, in the gravel and kunker below the regur, near Hingoli, in the Nizam's territories. No fossils have been yet found in the regur; but its position, extent, thickness, and the impossibility of accounting for it by causes now existing, warrant me, perhaps, in referring it to an epoch anterior to the post-Pleiocene or historic period.

2nd Group.—No sufficient data for fixing exactly the age of these rocks. The presence of coal, and other mineral and fossil indications, point to the Devonian or carboniferous groups.

3rd Group.—The clue to the approximate age of these rocks will be found in properly fixing those of the second,—a point of great importance in the geology of India, and to which I would fain call the attention and endeavours of all geological observers to fix, by searching for fossils, &c. If the rocks of the second group belong to the Devonian series, the hypogene schists must be either the rocks of the Silurian or Cumbrian series, as their unconformable stratification points out a greater age than the less disturbed and superimposed beds of limestone and sandstone. We need not even despair of finding fossils in gneiss, chlorite, and mica slates of India, since that illustrious geologist, Elie de Beaumont, displayed to the wondering eyes of the *savans* of Europe the instructive fact of belemnites (a fossil of the chalk period) in chlorite schist.

Geological Report on the Bagulkot, and part of the adjoining Talooks of the Belgaum Collectorate. By Lieutenant AYTOUN, of the Bombay Artillery.*

[Communicated March 1853.]

The district to be described is the area included between the rivers Kistna and Mulpurba on the north, south, and east, and a line drawn through Gulguleh, Kulludghee, and Badamee, on the west.

Its outline is nearly triangular, the two rivers forming the sides of a triangle, of which the line drawn through Kulludghee is the base.

In a north and south direction its greatest length is about fifty miles, and east and west about forty-five.

From the granitic basin of the Kistna at Beelgee on the north side, to the basin of the Mulpurba at Jalechal on the south, where the granite reappears, the whole of the district belongs to what the late Dr. J. G. Malcolmson termed the "Argillaceous Limestone Formation."

The sandstone, schists, and limestones composing this formation are here so altered by igneous agency as to render it probable that the granite, though nowhere visible on the surface within the area occupied by these rocks (except on the sandstone ranges which form the boundary of the formation on the north and south), extends below from one end to the other, and that these rocks are but a shell covering the Plutonic rock.

* Reprinted from the Transactions of the Bombay Geographical Society, vol. xi. p. 20,—1854,—ED.

The district as far south as the parallel of Kutteegeeree (or about sixteen miles south of Kulludghee) is composed of parallel ranges of sandstone and conglomerate, separated by valleys in which limestone and schistose rocks are developed. These standstone ranges trend in the direction of the dominant strike of all the rocks, from WNW. to ESE. The valleys are in general covered with black eotton soil, mixed up with which there is in many places a large amount of detritus of various rocks.

There are lines of dislocation and disturbance in a nearly NNE. direction, at right angles to the dominant strike of the strata, and eonnected with them are some striking phenomena which may in this place be alluded to.

1*st.*—On these lines of disturbance, narrow gorges or gaps have been formed through the hill ranges.

2*nd.*—The course of the rivers and nullas is much influenced by these lines; a river flowing in its normal direction to the east is deflected at right angles, and flows through, occasionally, gaps in two successive hill ranges.

3*rd.*—The rocks exposed in many of the nullas which follow these lines are more particularly disturbed and altered. The strata are deflected at right angles to their usual strike; the schistose rocks are often in a fragmentary state—forming a breccia; and the limestones are so indurated and silicified as to strike fire with steel.

These phenomena are the effects of an igneous agent acting at a period subsequent to that which elevated the rocks, and impressed them with their WNW. strike. I am inclined to think that they may be referred to the epoch of the Basaltic effusion, and that the disturbances are due to dikes of basalt underneath the locally affected rocks. The rivers being in flood during my stay in the district, I had not an opportunity of studying the best spots for the development of the igneous rock, nor at the gorges where the rivers have most probably laid bare the igneous agents; but at Bagulkot, where the Ghutpurba passes through a sandstone range, I observed basalt above the surface of the water. There is a breccia composed of fragments of limestone and red schist in a base of calc-spar at one place near Bagulkot; it passes into rhombohedral calc-spar rock, occupying a breadth of about twenty yards in an east and west direction. The direction of this dike (if it may be so called) is NE. by N. It will be described in detail when I come to notice the limestone valley of Bagulkot.

I do not consider this breccia as an igneous effusion, but that the breaking up of the rocks *in situ*, and a subsequent igneous or electro-galvanic agent, have given rise to this singular product.

There is a breccia at Kulludghee, through which wells have been

sunk to the depth of 30 feet. It is composed of fragments of quartz sandstone in a calcarco-argillaceous base. This, I am inclined to think, is the result of the breaking up of alternating bands of sandstone and schistose clay. The fragments are generally prismatic.

Wherever the sandstone becomes a quartzite, it is, almost invariably, divided by planes longitudinally and transversely, occasionally in such number that the prisms are scarcely an inch across.

A slight convulsive movement would be sufficient to dislocate and disorder the upper beds of sandstone so divided; and, accordingly, there are few spots on any one of the parallel sandstone ranges where the strike dip, or bedding, is visible, owing to the accumulation of the prismatic fragments of the broken up beds.

The south part of the district is composed of a widely extended sandstone tract. It presents a precipitous front to the Black Plain of the Mulpurba, the bounding hills being from 250 to 300 feet high. Granite appears below the sandstone of these hills at Jaleehal, and gneiss and felspar rocks extend across the Black Plain to the very foot of the Kupputgood hills. The trend of this sandstone tract approximates to that of the ranges to the north, taking the direction from Moorgoor as the point on the west, and Gudjunderghur as the eastern extremity. The trap deflects it to the north at Moorgoor, but it resumes its WNW. direction in the hills north of Belgaum, and onwards to the summit of the Ghàts. It is this sandstone which again appears in the Concan at Achre, Malwun, and Neotee (ten miles north of Vingorla), if an opinion may be formed from the general direction of the tract.

Adopting the views of M. Elie de Beaumont, regarding the period of the elevation of mountain chains, this elevated tract would be referred to his Pyreneo-Appennine system, traces of which he is already said to have found in the chain of the Ghàts.

The infusion of iron into portions of all the stratified masses, which appears to have characterised one epoch of igneous activity, has given rise to an abundance of iron ore in most parts of this district; and associated with the iron (and most probably effused at the same period), there are ores of manganese. The beds of all the nullas abound in titaniferous iron-sand, and the black soil also contains it in large proportion. There are traces of copper in the limestone near Kulludghee.

The limestone at Bagulkot has veins of manganese, but this metal is more frequently met with amongst the sandstone in veins of quartz. Specular iron is found in the same situation, but hæmatite in quartz and argillaceous iron ores are the more frequent varieties.

Iron has at one time been smelted very generally throughout the Talook, and the slag from the old furnaces may still be observed in different localities. The scarcity of firewood in the northern parts of the

district, and the introduction of English iron, have been the causes of the extinction of this manufacture. A few furnaces still exist in the southern part of the district, where there is more jungle on the hills. The ore selected for smelting is a very poor iron clay, and the iron produced from it is of inferior quality.

In the localities where the iron ores most abound laterite makes its appearance. On an elevated tract between Bagulkot and Kulludghee there are ridges of this rock, stratified and jointed, and following the same strike as the other rocks of the district. It is interstratified with sandstone and clays, and is, in my opinion, the clay of the locality with an infusion of iron, subsequent oxygenation having produced its present form.

The black soil of the valleys is frequently underlaid by a stratum of lateritic gravel, the detritus of ridges, perhaps, similar to those just mentioned, which diluvial action has worn down. This gravel may sometimes be seen concreted into a firm mass, and all trace of its conglomerate structure becoming obliterated, from one pebble being as it were fused with the other.

The junction of the Great Basaltic district with the granite of the basin of the Kistna occurs about three miles north-west of Beelgee. The gneiss and hornblende schists are much decomposed near the junction.

The trap passes below the first sandstone range on the north, and appears in the valley beyond, alternating with undulations of sandstone.

The nodular and prismatic varieties of basalt are the most common ; it is occasionally slightly amygdaloidal.

The black soil has not all been deposited in a quiescent state. It may occasionally be seen alternating with thin layers of fine gravel, as if there had been an intermittent action, viz. a stronger current prevailing at one time than at another. It is also frequently mixed with rolled fragments of iron, or quartz, and other rocks, and on being washed yields a fine quartzose sand, and a large quantity of titaniferous iron-sand. A basket which contained fifty pounds of this soil, and was taken from a field far above the present drainage of the country, yielded—

Fine quartzose sand and gravel (iron ore, quartz, &c. the pebbles rounded, and about $\frac{1}{4}$ to $\frac{1}{2}$ an inch in diameter)	$2\frac{1}{4}$ lbs.
Titaniferous sand	$3\frac{1}{4}$,,

Another basketful yielded as much as eight pounds of gravel, and a proportionate quantity of iron sand. Even when no pebbles are visible in the soil, I have found, on washing it, that they often abound.

The black soil does not appear to be of great depth in this district ; it

is often locally distributed about Kulludghee, where limestones and the bed of diluvium (which appears everywhere to underlie the black soil) appear on the surface. This is also the case about Bagulkot, until we penetrate to the valley of the Kistna, where a great depth of soil prevails.

The gravel bed below the soil will prove an useful auxiliary to the engineer, when, in the progress of improvement, roads shall be constructed across the black soil plains. I have observed in many of the black plains of the Southern Mahratta Country, that the country roads are often along the beds of nullas, which are selected on account of the hard gravelly bed exposed by the washing away of the soil.

I now proceed to describe in detail the several sandstone ranges, with their intervening valleys, commencing in the north, near Beelgee.

First Sandstone Range.

The strip of land between the Kistna and the first sandstone range is composed of granite, gneiss, and hornblende schist (the felspar and hornblende being in separate laminæ); the latter two rocks are in a decomposed state about half a mile from Beelgee.

The first sandstone range extends from Beelgee to Gulguleh in a slightly curvilinear direction, very nearly approaching a line WNW. and ESE. At Beelgee it makes a bend to the southward, and here strata are a good deal thrown about, and the hills project in short headlands with ravines, between them. The granite is well developed in these ravines, and is also visible about 60 or 80 feet up the hill, intruding on grits and conglomerates, which then form the lower beds of the sandstone.

A red porphyritic felspar rock of prismatic structure, but much decomposed, is seen at one point about 60 feet above the base of the hill. There is also here a rock composed of red felspar and translucent (and sometimes transparent) quartz, which much resembles red Egyptian Porphyry. Some varieties of it, when seen in blocks which have been slightly rounded, look much like a conglomerate, from the large fragments of quartz in them, but, on being broken, they have not the appearance of a mechanical origin.

Some of the beds of sandstone about Belgaum, of a highly crystalline character, have been, I think, derived from the abrasion of rocks like those above mentioned; and they are probably the ancient rocks of the district which have furnished materials for the lower beds of sandstone. I was at one time doubtful as to their origin; but having met with highly crystallised compounds, I now regard them as Plutonic Rocks.

The height of the first Sandstone Range, above the black soil plain of the Kistna, was ascertained by the aneroid barometer to be 200 feet.

The thickness of the different rocks composing the hill behind Beelgee is as follows, commencing at the top :—

1.	Quartzose sandstone, in beds 18 inches thick, white and reddish.	80 feet.
2.	Grits and conglomerates	40 „
3.	Granite and felspar rocks	80 „

The sides of some of the headlands have a terraced aspect, from the beds of sandstone projecting one beyond the other. The sandstone is not divided, as in other ranges, by innumerable divisional planes. It forms a good building stone, and is quarried with great facility. About three miles from Beelgee a soft variety is largely quarried for hand-mill stones.

On the summit, where the sandstone is hardest, and most nearly approaches to quartz rock, there are a few joints WNW. in the direction of the range. The dip of the beds is at a gentle angle (10°) to the south.

About three miles from Beelgee, on the road to Gulguleh, the trap of the Great Basaltic district makes its appearance in low hills, extending apparently from the Sandstone Range to the bed of the Kistna, and most probably crossing the bed of this river. In a south direction this offset of the Basaltic District is met with in the valley between the first and second Sandstone Ranges, where it penetrates to the borders of the schists and limestone, both of which it has broken up. Westward it continues to Gulguleh, when I observed it breaking in on the sandstone; and in the bed of the river near Gulguleh the river is probably crossed by trap dikes; but I had not an opportunity of verifying this, owing to the river being in flood. I observed, however, a rapid which indicated the existence of rocks below the surface; and the very name Gulguleh, which is applied to the village on either side of the river, probably owes its origin to the sound of water rushing between rocks. The effect of an igneous agent acting more or less in a north and south direction, transverse to the natural drainage of the country, would be, that dams or lakes would be formed, and these would exist only until the water flowing over the dam-head cut its way backwards through the dike, when the dam or lake would be emptied. That an obstruction of this kind formerly existed near Gulguleh is extremely probable; nor has it even now been altogether removed, if we may form an opinion from the breadth of land overflowed when the river is in flood. There are two varieties of trap rock in this part of the district—the prismatic and the spheroidal, both so common in the Great Basaltic district.

From Gulguleh I crossed the first Sandstone Range at its western extremity. A fault exposes a dark greenish thick-bedded flagstone,

which is cut up by divisional planes on the east side. This species of flagstone has been much employed by the Jains in their temples. It is not exposed in other parts of the district, that I am aware of.

The valley which lies between the first and second Sandstone Ranges is, on the east towards the river, covered with a great depth of black cotton soil, and no sections are exposed. But on the road between Kulludghee and Beelgee the black soil only occupies a narrow strip near the north side of the second Sandstone Range, while the rest of the valley to the foot of the first Sandstone Range is covered with a very sandy soil, the *débris* of the rocks which underlie it.

More to the westward, between Kulludghee and Gulguleh, trap alternates with sandstone ridges for several miles (see Section).*

At Malagerree the beds of sandstone are broken up into small prisms, which completely cover this side of the hill, and conceal the direction and dip of the strata. This effect has doubtless been produced by the trap, which is seen in the section emerging from both sides of the hill, and which, it may be safely concluded, passes below these broken up beds.

Second Sandstone Range.

This range is about 180 feet high. It is composed of sandstone and conglomerate, the former containing a good deal of felspar, the latter having jaspideous schist and quartz imbedded in a firm siliceous base. On the south side the sandstone is almost a quartz rock; it is broken up into fragments which conceal all the beds. The direction and dip of the strata were nowhere exposed at any of the points I visited. This fragmentary state of the sandstone beds is common to all the intermediate ranges between the first range at Beelgee and the great Sandstone tract on the south, at Badamee.

Were it not for the sections exposed at the different gorges where the rivers and nullas find a passage from one valley to another, the observer would be left in the dark as to the relative positions of the sandstone of the hills and the schists of the plains.

It is not improbable that the gorge through which the river Ghutpurba passes at Yerkul may afford a section exposing the relative positions of the rocks composing this range; and in this hope I visited the hills at Yerkul, but I was unable to complete my examination of the gorge on my first visit; and, owing to my health failing me, I never obtained another opportunity of revisiting this place.

* Plate XIII. fig. 1.—*Section from Gulguleh to where the Trap meets with the Schists and Limestone.*—*a*, Trap near Gulguleh; *b*, First Sandstone Range; *c*, Trap at Malagerree; *d*, Sandstone undulation; *e*, Trap; *f*, Low sandstone range, much veined with quartz, beds dip 70° south on the top, nearly vertical at the bottom and thrown about; *g*, Limestones and schists; the latter brecciated by the agency of the trap.

At its eastern extremity this range bends away at right angles—to the north-east; I did not examine the hills in that direction, having left the district before I could accomplish this object. To the west of Yerkul this range is continuous for eight miles only, it is then interrupted for several miles; but small ranges, prolongations of this, are met with to the north of Kulludghee on the Beejapoor road. In a narrow valley on that line, greenstone of a homogeneous texture is met with, intercalated among the limestone and indurated schists.

Between Yerkul and Bagulkot the rocks exposed in the valley on the right bank of the Ghutpurba, are shown in the section below.*

It is in this valley that the Ghutpurba makes one of those striking aberrations from its natural course which have already been alluded to. The subjoined sketch will best illustrate this.†

The crystalline greenstone, of which there is a great development in the valley to the right of the river, has not, I think, had any part in forming the gorges through the hills. It is intercalated apparently among the schists, and it is itself schistose in structure; but a dark basaltic trap, seen on the bed of the river, has most probably been the agent in the formation of the gaps through these hill ranges. The nulla which joins the Ghutpurba from the south also passes through gaps in two sandstone ranges to the south, before it enters the valley of the Ghutpurba at Bagulkot; and these gaps are nearly on a line with the two through which the river has been shown to pass.

Third Sandstone Range.

On the left of the gorge at Bagulkot, the hill is composed of a jasper-conglomerate and a quartzose sandstone, having here and there circular spots of a different hue from the base. These spots I take to be pebbles, which have retained their colour, although in texture they have been assimilated to the matrix. Conglomerates are not unfrequently fused into quartz rock in many metamorphic districts; and this quartz sandstone is a very near approach to a compact quartz rock, and very often passes into it.

The beds of the quartz sandstone are here broken up, and at only one point did I observe an appearance of bedding. Where rocks are cut up by numerous divisional planes, it is only by their relation to rocks of a different composition that their bedding can safely be decided; and

* Pl. XIII. fig. 2.—*Section of Valley between Bagulkot and Yerkul.*—*a*, Second Sandstone Range,—south side covered with *débris* of the beds; *b*, Indurated ferruginous schists; *c*, Greenstone, both crystalline and almost homogeneous; *d*, Green schists; *e*, Greenstone crystalline with a schistose structure; *f*, Green schists; *g*, Crystalline greenstone—slaty cleavage; *h*, Third Sandstone Range—sandstone alternating with schistose clays.

† Pl. XIII. fig. 14.

here the jasper-conglomerate on the north side of the hill was the only rock to guide me. Judging by this, and by the dip of the rocks on the opposite side of the gorge, I determined the strike to be WNW., dip 40° south.

This accords with the dip of the limestone in the valley, and with the schists and sandstone of the next range, where a clear section places the bedding there beyond all doubt. On the right of the gorge there is a hill with a temple on it composed of a fine laminated clay, of a whitish colour not unlike Kaolin, which is excavated by the natives for whitewashing, &c.

This clay is met with on the summit of the hill; but to the eastward, where the range attains a greater elevation, a schistose clay—probably the equivalent of this—is found overlaid with quartz sandstone, which dips south at an angle of 27°. On the north side, the strata are so thrown about and dislocated as to defy any attempt to lay them down on paper. There is a good deal of a conglomerate composed of quartz pebbles in a ferruginous siliceous paste, lying about in blocks on Temple Hill. It resembles the diamond conglomerate of the south of India. In the ranges to the south of this a similar conglomerate is not unfrequently met with.

More to the eastward, about five miles from Bagulkot, I crossed this range to Munneckuttee, where the following section was obtained.*

At this point there has been an effusion of iron, evidenced on the north side by the fergination of quartzose schists, and on the south side by the laterite. But not only is the iron effusion apparent in the rocks on either side of the hill, for on the hill itself the sandstone may be observed in different stages of fergination up to a rich granular quartz iron ore; and that the sandstone has not originally, on its deposition, contained this iron, is proved by the fact of the ore being still unoxidised.

About ten miles from Bagulkot, on a prolongation of this range, there are low sandstone hills, with veins of quartz containing specular iron-ore. The sandstone here has a red tinge, and is more granular than that at Bagulkot; the beds are not so much broken up, and the stone is employed in buildings.

The ridge *a*† seen in the section, on which the fort and town of

* Pl. XIII. fig. 3.—*Section five miles east of Bagulkot.*—*a*, Ferruginated schists, with much quartz and iron ore; *b*, Sandstone beds broken up into prisms, ½ an inch to 4 inches across; *cc*, Laterite ridges, with a great deal of their detritus lying about; *d*, Sandstone detritus.

† Pl. XIII. fig. 4.—*Section of the Limestone Valley of Bagulkot*—(*about four miles*).—*a*, Ridge of schist and quartz breccia; *b*, Granular limestone; *c*, Compact limestone with chlorite slates; *d*, Lithographic limestone alternating with white limestone, coloured with chlorite in part, and (*e*) schistose limestone passing into clay-schist; *f*, Fourth Sandstone Range, composed of sandstone alternating with schist.

Bagulkot are situated, is about 50 or 60 feet above the level of the river Ghutpurba, which washes its base.

In a well I observed a section showing a breccia of schistose clays and fragments of quartz sandstone; and this breccia probably constitutes the greater portion of this ridge: but at its western extremity it shows large blocks *in situ*, of a very beautiful rock. Some of the blocks are entirely composed of brilliant crystals of quartz and hæmatite; other blocks are found to be a breccia of angular fragments of sandstone cemented with hæmatite, and this latter sometimes so predominates as to produce large blocks of iron ore. Crystals of quartz ore are imbedded in the body of the hæmatite in a singular manner. I believe that in a rock having these characters, and occupying the same geological position, diamonds and several other gems are occasionally met with in the diamond districts of the south of India.

As I shall afterwards explain, I do not suppose the breccias in this district to be all volcanic effusions, most of them having resulted, in my opinion, from Plutonic disturbance, which has disordered and jumbled up the alternating strata of sandstone and schists.

At the east gate of the fort of Bagulkot an impure limestone is seen in a nulla, dipping south at an angle of about 15° or 20°. To the south of this, again, schistose clay is exposed: but the succession of strata is not clear here, owing to the covering of detritus and black soil; and, owing to the same cause, it is only occasionally that the rocks present themselves above this superficial covering throughout the valley, so as to admit of their dip and direction being noted. In the nullas which cross the plain in a north and south direction they are better exposed than in other places; but, as I have already mentioned, there are lines of disturbance where the rocks are more highly altered than in other places, and to generalize from the phenomena presented by these would be to lead to erroneous conclusions.

I have given in the section what appeared to be the dip of the rocks which had been least affected by local disturbance. On the same strike I had found the limestone and schists dipping at the angles given, and also nearly vertical, or with the bedding so obliterated as to appear to be vertical.

In so disturbed a district it is not, perhaps, of much consequence to fix the dip, unless for the purpose of ascertaining where an anticlinal axis exists, or where the strata are folded over. My observations at Bagulkot did not detect either one or the other of these mechanical effects of a Plutonic agent, although at Kulludghee there is some reason to believe that such may have occurred. The limestones near the parallel of Bagulkot are either impure granular limestone, or a slaty marble of a compact texture, with thin plates coloured by a veining of chlorite, and occasionally talc.

In a nulla south of the Fort the limestone has a gnarled and twisted appearance, like some varieties of gneiss. It there loses all trace of bedding. The contorted appearance of this rock is due, I think, to bands of an argillaceous character, which have, on the heating process to which this rock has been subjected, assumed a wavy outline.

Near the Fourth Sandstone Range the limestone is much purer than in other places in this valley. One variety, of a very pale colour, breaks with a fine conchoidal fracture, and has the texture of lithographic limestone; it alternates with a white limestone.

On polishing pieces of the lithographic limestone which appeared perfectly free from foreign ingredients, the small siliceous spots which have frequently been noticed as a great defect in this stone became apparent. In hand-specimens some of the white limestone is a pure crystalline marble, which might be pronounced statuary marble; but I never found that the bed from which the specimens were taken continued pure for any distance.

Between Bagulkot and Seroor a pink or salmon-coloured limestone is met with, on nearly the same strike as the rocks I have just been describing. The same variety of limestone is rarely met with on the same line of strike; and this is doubtless due to the many alterations which the beds have undergone, the metamorphosing agent acting transversely to the strike.

Calc-spar Breccia.

Near the village of Guddunkeeree there is a breccia deserving special notice. I have termed it Calc-spar Breccia; but it is composed of schists and limestones of all sizes in a base of calc-spar. The limestone on the surface at this point is principally a banded rock, buff and blue limestone alternating; it is nearly vertical. There are other limestones besides this one, but it appears to be divided most clearly by the brecciated rock which I am about to describe. The following ground-plan of the rocks at this place exhibits the strike of the limestone cut through by the breccia, and the direction of the fissure occupied by the latter.*

The limestone on the east side is at first seen to be fissured NE. by N., and the fissures, which do not exceed a quarter of an inch in breadth, are filled with calc-spar; still further west these increase in size, and become thick veins, but still with the limestone rock predominating; these veins, however, send branches off in all directions, and pieces of

* Pl. XIII. fig. 13.—*Section of the Calc-spar Breccia at Guddunkeeree.*—A A, Limestone; B, Rhombohedral Calc-spar; C, Calc-spar Breccia; *a*, Limestone in alternate blue and buff bands, each about two inches thick; *b*, Strings of calc-spar veining the limestone in a NE. by N. direction; *c*, Thick veins of calc-spar, irregular in direction; *d*, Breccia of limestone with calc-spar base; *e*, Ditto, with the calc-spar in excess; *f*, Rhombohedral calc-spar rock, not less than twenty yards broad; *g*, Continuation of limestone.

the limestone are isolated as it were in calc-spar. More to the west the fragments of limestone and also schist are confusedly thrown about in a matrix of calc-spar, and these fragments decrease in number until the rock ultimately becomes pure calc-spar. The calc-spar rock is covered with several feet of fine alluvial soil, and does not appear on the surface as the breccia does. As the stone is used by the natives for sprinkling on days of festivity, to break the monotony of the hue given by the cow-dung, and to produce a glittering effect, two small excavations had been made in the field for the purpose of extracting the mineral.

With the view of ascertaining whether lead or other metals, which are often associated with calc-spar in veins, existed here, I employed men to increase the size of the excavations in an east and west direction, as I thought that, if metals did exist, some indications would be found at the junction of the calc-spar with the other rocks. For upwards of 15 feet the calc-spar was laid bare at one of the excavations without coming to the termination of that rock ; and, from observations made on either side of this, I do not think there can be a less breadth than 60 feet of this dike. A growing crop of grain in other parts of the field prevented further investigation. How far the calc-spar dike extends lengthways is not apparent ; but two hundred yards to the north the valley is bounded by a sandstone range, and here probably the limestone terminates.

Underneath the soil and overlying the calc-spar rock there was at one point a bed of conglomerate Kunker, not the nodular variety which is so common under the black soil, but *sheet* Kunker, which is met with in a great many parts of the Southern Mahratta Country, and which appears to have been deposited immediately anterior to the formation of the black soil. In a cavity of the calc-spar there were rolled pebbles, and diluvial action was otherwise apparent in the denudation of the calc-spar, and in rolled pebbles in the lower parts of the alluvial soil.

In the rocks (limestone) to the east of Guddunkeeree rows of holes may be observed on the upper surfaces of the more massive kinds, which have lost their bedding. I was at a loss to conceive the origin of these until I met with one hole still retaining a concretion of calc-spar. All of these cavities have at one time been filled with calc-spar, which has since decayed. One of the holes is sufficiently large to form a small tank during the rains, and along its edge may be observed two rows of small cavities with their diameters varying from half an inch to two inches.

The Limestone valley of the Bagulkot is not continuous with that at Kulludghee, although they are on the same parallel, and this is owing to a cross elevation of sandstone and schists.

Before passing to the Kulludghee valley it may be as well to describe

this elevated tract—the only one in the whole district, that I know of, where Laterite is well developed, and where its relations to the other rocks are clearest.

This section* is intended to represent the undulations passed over in crossing from Bagulkot to Kulludghee. Nearly the whole of this tract abounds in iron and manganese ores, never seen in veins *in situ*, but covering large spaces from broken up veins. The Laterite appears here in ridges in a direction west by north, which is also very nearly the direction of the slate and schist, and of the sandstone hills.

The section I am about to give is not at right angles exactly, being in a NNW. direction; but it is transverse, and embraces the whole elevated mass.†

The original components of the whole of this tract have been the sandstone and the blue clay. The Plutonic agent which elevated the tract infused iron into the clay, which, oxidising, has produced the Laterite; the sandstone has been turned into quartz and into quartziferous iron ore. Such was my interpretation of the phenomena after a careful examination of this very confused tract.

The blue clay may be well studied at the section of Cromlech hill, where the river Ghutpurba impinges on its western side, and is deflected to the north. Here in one place it has an almost massive appearance, and again in another it is finely schistose, while the laterite ridge at the foot of the hill shows it in another form with an infusion of iron.

The upper part of this hill is composed of quartz sandstone, cut up as usual by innumerable planes, and covered by prismatic fragments of a few inches diameter, resulting from an upheaval of the beds. The prisms are so small that even the rude architects of the Cromlechs and circles of stones which are found on the top of this hill have been compelled to resort to the Laterite ridge between for materials to form the circles, and to the valley of Kulludghee for large blocks of limestone with which to construct the Cromlechs.

This tract has its ranges of sandstone following the dominant direction; but at its western end, where the edges are presented to the valley

* Pl. XIII. fig. 5.—*Section of the elevated tract between Bagulkot and Kulludghee.*—*a*, Sandstone, blue schist, slate, quartz, iron ore, manganese, and laterite; *b*, Sandstone, laterite, great quantities of iron ore and manganese; *c*, Sandstone, slate and schists, nearly vertical, east and west.

† Pl. XIII. fig. 6.—*Section of the elevated tract between Bagulkot and Kulludghee, nearly transverse to the last.*—*a*, Cromlech hill, composed of sandstone and blue schist; *b*, Ridge of laterite W. by N., jointed in blocks between *b* and *c* there is a deal of laterite detritus, followed by blue schistose clay and quartz with iron ore; *c*, Laterite ridge jointed in blocks; *d*, Blue schistose clay W. by N.; *e*, Sandstone and conglomerate hill; *f*, Ridge of laterite W. by N.—the rest of the valley is covered with detritus of sandstone and soil; *g*, Sandstone hill; *h*, Laterite ridge W. by N., jointed like all the others; *i*, Blue schistose clay and quartz with iron ore.

of Kulludghee, the schists and limestone forming the valley are seen near the foot of the hills with a strike at right angles, and the rocks do not recover from this deflection for upwards of half a mile from this range or elevated mass of rocks.

Returning to the Bagulkot side of this elevated tract a low range of hills, nearly on a line of strike coincident with that of one of the hills forming the tract, lies immediately to the south of Bagulkot. The sides of this range are everywhere covered with the prismatic *débris* of the broken up beds of quartz sandstone, of which this range is principally composed.

But at one point, nearly in the same line with the gaps in the two ranges to the north, through which the Ghutpurba flows, there is a narrow gorge in this range through which a nulla finds its way to join the river at Bagulkot, and at this gorge there is a clear section of the hill exposed. The bursting of a bund, which formerly dammed the valley beyond, has swept away all *débris* which could obscure the bedding, and a section, the clearest in the whole district, and one which places beyond all doubt the alternation of the schists with the quartz sandstone, is obtained.

I consider the determination of this fact as important, because, from the obscurity caused by the breaking up of the beds of this sandstone, and from its superior position to the other rocks, Captain Newbold and Dr. Christie (who have published passing observations on this district) both seem to have thought that this sandstone was unconformable to the schists, and rested upon them. Had such been the case this formation would have differed from the other argillaceous limestone districts in India, where, although the sandstone is superior to the schists and limestones in the stratigraphical position, the whole are conformable.

It was after the examination of this section that I came to the conclusion that many of the apparently volcanic breccias were merely the effects of the then alternating beds of schists and sandstone being jumbled together *in situ;* for it will be observed that, in the accompanying section,* sandstone in thin bands an inch or two in thickness at one point alternates with the schist or schistose clay. As these bands of sandstone are subdivided into rhombs, the mechanical effect of a

* Pl. XIII. fig. 7.—*Section showing the Quartz-Sandstone alternating with Schistose Clay, about three miles south of Bagulkot.*—*a*, Sandstone, cut up by innumerable divisional planes; *b*, Schistose clay, 18 feet thick; *c*, Sandstone, 18 feet thick, cut up by divisional planes; *d*, Schistose clay, 8 feet; *e*, Thin bands of sandstone alternating with schistose clay; *f*, Sandstone cut by vertical planes and by others, 25° N. dip; *g*, Schistose clay, ragged in appearance; *h*, Limestone valley of Bagulkot.

Height of hill about 70 feet. The fragments of sandstone form a mass eight or ten feet thick over the rocks at (*i*), and the beds are prolonged to near the summit, as seen in the section, which has been exposed by the bursting of the bund.

convulsive movement would be sufficient to dislocate and disorder the mass, and to mix the sandstone fragments up with the clay; and it is this cause, I think, which has produced the confused mass of clay and sandstone, through which wells have been sunk to a considerable depth at Kulludghee.

The valley beyond this hill is covered with soil through which *débris* of iron schists, iron and manganese ores, and quartz are profusely scattered (see Section).*

Another gorge is met with in this west range, in the same line as the last gorge, which had formerly been artificially bunded. I was informed that on this Sandstone Range there were two of these gorges, and that both were formerly barred by artificial means, but that floods had swept them away.

These gorges have played a most important part in the former agriculture of the country, and it is singular to find the natural drainage of the parallel valleys running at right angles to the bounding hills, so as to admit of this artificial damming. Beyond this range the sandstone appears in one or two ridges about 60 feet high; towards Kutteegeeree they are all cut up by divisional planes, and have *débris* on their sides. The limit of the schists and limestones I have marked about three miles south of that village. The limestone, in the form of a fine schistose variety, is met with at the nullas which in the map may be observed a little to the south of the village. The schist appears in several places nearer Badamee for a few miles. This part of the country is very much covered with black soil, which, however, terminates a mile beyond the limit of the schists, and we then enter the great Sandstone Tract of Badamee.

On the borders of the black soil a detritus of jasper quartz and other pebbles is met with.

The hills at Badamee attain a height exceeding any of those that I have described, being upwards of 250 to 300 feet high (I judge by comparison, for during my stay here the weather was so rainy that I could not use the aneroid barometer).

At the several points where I examined the sandstones at Badamee and Jaleehal the bedding appeared to have been destroyed. There were cracks nearly horizontal, and others crossing them; but both appeared to me to be too irregular for true basis of deposition, and in a quarry on the top of the range at Jaleehal, where these lines were observed, there was also a part of the sandstone having a distinctly schistose character, while all around was massive, nor was this band visible beyond one side of the quarry.

* Pl. XIII. fig. 8.—*a*, Hill described in last section; *b*, Valley covered with detritus of soil, &c.; *c*, Fine red glossy schists; *d*, Sandstone ranges, beds dip S. at 80°. This hill is profusely veined with quartz in an east and west direction.

From the above circumstance, and from the appearance of curite (granite) and felspar rocks below, I concluded that the original lines of deposition had been obliterated and new lines marked by the action of the igneous agent. A river has apparently washed the base of the Badamee hills, where there is a considerable depth of fine sand, similar to what a river would deposit near the hills which it was wearing away. The Ghutpurba at Kulludghee is now throwing up banks of fine quartzose sand close to where it impinges on Cromlech Hill.

There is much more felspar in the composition of the sandstone from Jaleehal to Kutteegeerec than in the sandstones met with to the north. South-east of Bagulkot, at Serroor, the beds of sandstone and conglomerate have a good deal of schist in their composition, and the fragments when numerous give a schistose structure to the conglomerates; and at Kutteegeeree, the ranges of quartzite there have a cellular appearance, from the deeay of the felspar on the exposed surfaces.

At Badamce the hills appear to be entirely composed of sandstone, and there being nowhere else so great a thickness of this rock to the north, this cannot be a repetition of the sandstone met with in the hill ranges. It may be that (as the dip appears to be south in the district occupied by the limestones, sehists, and parallel hill-ranges) this tract is composed of the upper beds of sandstone of the same formation, the lower beds being the schists, &c. to the north.

The weather was so rainy when I passed through Badamee that I had no opportunity of examining the neighbourhood in detail, and I have introdueed this track in order that the district from the granite on the north to the granite on the south may be considered as a whole. My examination merely enables me to give its general features. At Moorgoor, however, I must not omit to mention that the hill consists of conglomerate (puddingstone of large quartz pebbles in a ferruginous argillaeeous base) on the top; beds of sandstone immediately below; and clays near the base. There is a sandstone near the top of a friable nature, almost entirely composed of red felspathic granites. A variety of this is, I believe, quarried in the same range at Pursghur, for stones used in grinding sandal-wood. Greenstone porphyry has penetrated to the summit of the sandstone hills north-west of Moorgoor, and appears as a centre nucleus.

Valley of Kulludghee.

The rocks in this valley, which is on the parallel of the Bagulkot one, are extremely eonfused, and the sections transverse to the dominant strike show that the different stratified masses have been brought to the surface in the most irregular manner within very limited localities. I

will begin by giving a section from the First Sandstone Range on the north to the Range south of Kulludghee.*

Where the trap approaches the limestone the rocks are much broken up on lines running NNE. The sandstone ridges are veined with quartz parallel to the strike. At the village of Katurke, about three miles from Kulludghee, there are large excavations in beds of argillite, which formerly furnished honestones for the supply of the Madras Presidency. They are now partly filled up with rubbish, and have not been opened for many years. Near Moodhul, however, I was told honestones were still quarried.

At Alyoondee there are some fine-coloured marbles—coloured green principally with chlorite,—and in the vicinity a fine-grained lithographic stone. There are beds of flagstones at this village which are associated with the limestone, but black soil conceals the relations of these rocks. Nearer Kulludghee than the two villages just mentioned (which are on the further side of the Ghutpurba), limestone prevails. Its bedding is in general obliterated, but when observed it has a southerly dip.

Crossing the river to Kulludghee, the first rock which presents itself is a thin-bedded flagstone passing into shale, both of which are quarried for building. This is commonly termed slate, but it has not the true slaty cleavages; its planes are undoubtedly those of deposition. The same flagstone, however, in other places does acquire a true change at a considerable angle with the places of deposition, which may be detected by the coloured bands crossing the cleavage plains of the slate. The flagstone is well exposed in the quarry, it dips 37° NNE.

The strata within fifty yards are deflected considerably.

The limestone nearest the slate has a strike W. by S., and a southerly dip. The limestone nearest the flagstone has a strike N. by W., and dips south. The slate is W. by N., and dips south. I think it is not unlikely that the slate on the other side of the limestone is the flagstone with a new cleavage impressed upon it.

Proceeding south, limestone and schists, twisted and contorted, and with bedding obliterated, are met with along this line, which is one of the disturbed NNE. lines.

Overlying limestone and schist there is a hard concretionary limestone with fragments of quartz in it. Near the bazar it sometimes presents a

* Pl. XIII. fig. 8.—*Section of the Plain of Kulludghee*—(*about twelve miles*).—*a*, First Sandstone Range; *b*, Trap, principally spheroidal, like that in basaltic district; *c*, Undulation of sandstone broken up; *d*, Trap; *e*, Sandstone, dip southerly; *f*, Limestone and schists, much disturbed; *g*, Argillite beds, yielding honestones; *h*, Limestone bedding, much obliterated; *i*, Thin-bedded flagstones and shales, dip north; *k*, Limestone and slate, dip south; *l*, Limestone and schists, much broken up; bedding obliterated in most places, often very cherty; *m*, Ditto; *n*, Limestone, whitened and silicified; *o*, Flagstones similar to *i*; *p*, Schistose clay below sandstone of the hill; *q*, Range of sandstone.

pisolitic appearance, the spots being of a reddish hue when the stone is broken. This belongs to what has been termed the sheet kunkur formation. It extends for more than a mile and a half at Badamee, but here I did not trace it for many hundred yards.

Immediately beyond it we came on a great deal of red ferruginous gravel, with occasionally a consolidated block of laterite coated with manganese, which appears as a bluish-black efflorescence on the surface of the block. This ferruginous gravel is often found mixed up with the black soil, and it is often seen underlying it. It is probably the result of diluvial action just anterior to the deposition of the soil. It is found on the higher ridges or undulations which have no black soil on them. Near the cross dislocation of sandstone and schists forming the hills on the east of this valley, there are quartz and iron ridges. The quartz is cavernous, and the cavities are filled with iron. Scattered over the undulations here and there are vast quantities of iron ore and manganese.

The camp of Kulludghee is partly built on the limestone which forms its western side, partly on the red ferruginous gravel before mentioned, and also on a rock in a fragmentary state forming a breccia. The wells are sunk through this broken-up mass for 30 feet. It appears to be a schistose clay with some calcareous matter in it, and fragments (of prismatic form) of sandstone. In the nulla near it, schists and bands of quartz appear on the surface, and to the south of them, a limestone with a very wavy appearance, due to argillaceous bands projecting from the surface, which in the heating process have assumed this outline.

About two miles north of the Ghutpurba, in a nulla which joins it from the south, the schists are observed deflected NNE., like those near Bagulkot, and also like many others in this plain. On the same line, limestone of a very white colour, fine-grained and extremely hard. Beyond it flagstones are again quarried. These flags dip to the south, and as there is an appearance of the limestone close to the camp, dipping north, it may be that an anticlinal axis exists between the Ghutpurba river and the first Sandstone Range to the south. I lean, however, to the opposite opinion, and consider the flagstones on the north as distinct beds from the other.

At the village of Kuchcedonee, about four miles from Kulludghee on the Belgaum road, on the top of an undulation, limestone is exposed for about a hundred yards on one side of the road. The limestone has a strike nearly east and west, and dips south at an angle of 45°. It overlies a schist which is a good deal broken up. It is granular in texture, and of a slaty structure. The plains are covered with talc, and are often coloured green with copper, which also permeates the limestone in thread-like forms. Almost every fragment of the limestone has a greater or

lesser proportion of the copper coloration. This general diffusion of the copper colouring would lead one to hope that this metal may yet be found in a concentrated form in veins. In the Ural mountains it is near the junction of the limestone with igneous rocks that this metal is so abundant, and the analogies between that range of mountains and the Ghàts are so numerous as to induce one to believe that their metaliferous characters will also be found alike.

From the circumstance of the limestone invariably appearing in valleys and never being elevated into hills in this part of the country, it is very seldom that any large portion of it is exposed, the diluvium and black soil covering so large a part of every valley and concealing the rocks. I am aware that copper has been found in the Madras Presidency diffused through masses of the rock, but nowhere concentrated in veins ; and to account for this want of concentration Lieutenant Ochterlony, of the Madras Engineers, applied the doctrine of the German geologists, viz. that large masses of stratified rocks being necessary for concentration,—that condition was not present in the districts he surveyed, where the rocks were almost entirely igneous, and hence iron, copper, lead, &c. though extremely diffused, were nowhere concentrated. This does not, however, occur in the Kulludghee districts; the stratified masses predominate over the igneous, and the iron and manganese, though diffused in most cases, are also concentrated in veins of quartz.

The limestone and slate are seen in the gorge leading across the Sahapoor hills to the westward. They are on the same strike as those a few miles south of Kulludghee. The slate is thin enough for roofing purposes, but on the surface the planes of deposition limit the size of the slabs very much. There are doubtless thicker beds below. The natives make no use of the slate ; so far as I am aware of, it is the flagstones that they use.

List of Rocks, Ores, and simple Minerals in the District, and the localities where they are met with.

Granitic Series.—1. *Common granite*—Beelgee, and parts of the valley of Kistna adjacent to it.

2. *Eurite*—ditto, and Jalcehal and neighbourhood.

3. *Gneiss*—ditto, ditto.

4. *Argillite*—Hornestone or Novaculite quarries at Katurki, and other places in the neighbourhood of Kulludghee.

Sienitic Series.—1. *Sienitic granite* at Jalechal.

2. *Hornblende schist*—Beelgee.

3. *Greenstone*—Valley NE. of Bagulkot, valley NE. of Kulludghee, also in the valley of the Kistna.

4. *Basalt*—Bagulkot bed of river, also four miles north of Kulludghee, and in the Great Basaltic District to the north.

5. *Amygdaloid*—ditto.

Crystalline Limestones.—1. *Granular Limestone* abounds at Bagulkot and Kulludghee; in general it contains a considerable amount of talc, which gives it a slaty cleavage; very beautifully coloured marbles are occasionally met with.

2. *Dolomite.*—This rock does not appear to have any stratigraphical position, but is met with in various places where there has been an effusion of magnesia.

Uncrystalline Sedimentary Rocks.—1. *Conglomerates*—on most of the Sandstone Ranges.

2. *Sandstones* of every variety, but principally a quartz sandstone.

3. *Flagstones and Shales*—neighbourhood of Kulludghee.

Compact Limestones.—In great abundance in the neighbourhood of Bagulkot and Kulludghee.

Calcareous Tufa.—Bagulkot, Kulludghee, and Badamee.

Marl—Kulludghee contains recent shells.

Ores and Simple Minerals.—1. *Quartz* everywhere.

2. *Calc-spar*—most abundant near Bagulkot, village of Guddunkeeree.

3. *Copper*—coatings on the laminæ of a talcose limestone at the village of Kucheedonee, about four miles from Kulludghee; the rocks, as far as they are exposed, have this copper coating. Dissolved in acid it effervesced, and gave a metallic coating of copper on iron.

4. *Specular Iron*—in quartz veins in the range of hills south of Bagulkot, and at the village of Benhuttee.

5. *Brown Hæmatite* abounds on the elevated tract between Bagulkot and Kulludghee.

6. *Quartz Iron Ore*—Sandstone hills, wherever an effusion of iron has taken place.

7. *Argillaceous Iron Ore*—in almost every part of the district.

8. *Psilomelane* (compact manganese ore)—elevated tract between Bagulkot and Kulludghee in great abundance.

9. *Pyrolusite* (ore of manganese)—ditto, ditto.

10. *Magnetic Iron Ore*—in crystals disseminated through masses of rock.

In concluding this Report, I may mention that the observations of which it is the result were made during two months of an unusually wet monsoon, and under the further disadvantage of indifferent health, which compelled me in the end to give up the survey of the district before it was completed.

Incomplete, however, as my examination of the district has been, I have attempted to describe a portion which may be taken as a type of the whole.

Geological Structure of the Basin of the Mulpurba in the Collectorate of Belgaum, including the Gold District. By Lieutenant AYTOUN, of the Bombay Artillery.*

[Communicated December 1852.]

The basin of the Mulpurba is bounded on the west by the last ridge of the great overlying trap formation of the Deccan. On the north by the sandstone hills of the Gokauk belt, which here sends an offset to the south, meeting an elevated belt of schistose rocks which forms the eastern boundary.

The river Mulpurba in its course to the north-east has forced a passage through the sandhills near Pursgurh.

The trap range on the west is about 400 feet high. The elevated tract of schistose rocks on the east has a general elevation of nearly 300 feet above the level of the river, and on this elevated ground are situated Taygoor, Kittoor, and Dharwar. The water-shed runs in a direction nearly ENE., from Kittoor to Pursgurh.

The rocks met with in the basin are the hypogene schists principally, and they predominate in the following order, proceeding eastward, viz.:—micaceous schist, talcose schist and slate, and chlorite schist and slate. Associated with the mica schist in one part of the basin there is clay slate, and in the chlorite slate district there is a red argillaceous rock, sometimes thick-bedded, at other times appearing finely schistose.

All the rocks have been subject more or less to the disturbing and metamorphic effect of igneous agency which appears to have been at work not far below them. Trap and sienite are developed in many places throughout the basin, and are frequently visible in nullas and depressions. I did not, however, meet with any hills composed of these igneous rocks, although about Hoobly and Taygoor the trap is seen projecting from the surface in long ridges, which, being jointed by planes at right angles, appear like lines of blocks. The trap a few miles from Hoobly assumes quite a different aspect from any varieties I have met with in the great basaltic district.

It is here a crystalline greenstone with white and light-green colours. It retains the same characters wherever I have met with it among the schistose rocks. Specimens from Dharwar, the Kupputgood hills, and Bagulkot, all present the same appearance. It is sometimes porphyritic, long needle-shaped crystals of felspar traversing it.

Having thus broadly laid down the geological features of the basin,

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I now proceed to give a few details regarding the structure of certain parts which came under my observation.

Proceeding from Belgaum to Dharwar the road lies across the trap range, which forms the western boundary of the basin.

On descending the east side of this hill the first thing which strikes the attention is the abundance of fragments of iron ore of a schistose structure, and quartz. Many of the fields are covered with those fragments which subsequent observation shows to have come from large ridges of ferruginated and quartzified schists.

For many miles in different directions these are the only pebbles met with among the soil.

Nearer the centre of the valley accumulations of quartz detritus, mixed with soil, are seen in some of the natural sections.

On crossing the river Mulpurba the elevated tract of schistose rocks on the east of the basin is entered.

Here a new and striking feature (and one, I think, bearing on the auriferous character of the district) presents itself. Parallel ridges, composed of alternate bands of quartz and iron ore, having a direction nearly north, and south, are met with at intervals of a quarter or half a mile, and on their flanks a large accumulation of quartz pebbles, occasionally mixed with small red fragments of laterite or argillaceous iron ore. They are of no great height, not probably more than 150 feet above the lowest part of the valley at their foot, but they have attracted the attention of every Geologist who has visited the district.

I traced them throughout the line of country which lies between the Mulpurba and the Kupputgood hills, and I learn, from the writings of Captain Newbold, that they are met with at Bellary and in Sondur. They appear to be strictly analogous to the quartz ranges and metamorphic parallel bands of the Ural mountains and those of Australia, and like the latter, I conclude, they will be found to characterise the "gold zone" of this district.

About Byl Hongul, a village ten miles to the north of the Dharwar road, these ridges are still met with, but there they are principally jaspideous, and appear in long continuous masses, and also jointed at right angles, forming a succession of immense blocks of jasper.

In this part of the basin the rocks are chlorite slate and red argillaceous slate, and they are concealed, except in a few places, by a covering of black soil. The streams which contain gold flow through cotton fields. The chlorite slate is only occasionally visible in their beds. There is a detritus of jasper, jaspery iron ore, quartz, and occasionally greenstone and sienite, mixed up with the black soil which here covers the undulations of the ground. At one point I observed a jasper and iron band protruding from the black soil; and from the

fragments met with among the black soil and in the bed of the stream, I am inclined to think that these ridges must be very numerous, although not visible. They have been broken up, and their materials spread over the undulations near them. There is a very large amount of titaniferous sand and magnetic iron in grains among the detritus and black soil. In washing the gravel in the bed of the stream this becomes apparent. The magnetic iron appears not only to be associated with the specular varieties in the jasper dikes, but also to be disseminated through some of the rocks in scattered crystals. Iron pyrites in cubical crystals is met with in the chlorite slate, and it also appears disseminated in scales and coatings on the jaspideous rocks.

Underneath the black soil I observed, in a section on the bank of a stream which was auriferous, a deposit of fine concrete, a rock which has a very extensive distribution over many parts of the Southern Mahratta Country, near the great Basaltic district, as well as within that trap region.

Below this fine concrete, the pebbles of which do not much exceed the size of peas, I observed at the same place a mass of concretionary limestone imbedding angular fragments of quartz. This apparently rested unconformably on the chlorite slate in the bed of the stream. The fragments of quartz were not of an uniform size, being from two to nine inches in diameter.

At Belowuddee, between two of the jaspideous ridges, which are here about two or three miles apart, some of the streams contained gold. There was black soil here also, and underneath it a bed of gravel from two to five feet thick, resting on a decomposed felspathic whitish rock; on the higher grounds about Byl Hongul there were decomposed rocks, but whether of a plutonic or sedimentary character, I did not succeed in determining, on account of the extreme disintegration which had taken place; but at Belowuddee this action has been much more intense, and the rocks are either converted into clays, or rapidly approaching that stage of decomposition. The red argillaceous slate, an associate of the chlorite slate, is largely developed here.

Between Byl Hongul and Belowuddee, in the valleys, there is much greenstone.

The concretionary limestone before mentioned is again seen in the stream, here imbedding angular pebbles of quartz.

The Kupputgood Hills, or Gold District.

At Dumul, the main range of the Kupputgood is about 1,000 feet high. It presents a bold and almost linear outline, in which respect it differs most strikingly from the mammiform and conical outlying and subordinate ranges.

The sides are exceedingly steep, and are covered by red argillaceous slate, which on the east side is converted into quartz and iron slate. The nucleus of the hill, which I suppose to be granite, is not, so far as I am aware, uncovered, but on the east and west, granite is largely developed. Between Dumul and this main range there are two outlying ranges, having a direction NNW. They are composed of talcose and micaceous slate of a highly quartzose character. Intercalated, too, among these are beds of altered slate converted into iron ore.

Mica-slate and gneiss appear at Dumul, and are the rocks principally met with in the plain which extends from the Kupput Hills northwards to the sandstone at Badamee and Gudjunderghur.

Red felspar granite and sienite are seen in veins and dikes, traversing the gneiss.

In the section of the Soltoor Pass which lies between the main range and a system of hills to the north, a prolongation of the range, it will be seen that trap makes its appearance in many places.

At Dumul a trap porphyry is seen among the gneiss, also dark spheroidal trap. Between that and Dhonee the trap is in general decomposed, it is mostly of the spheroidal variety, and there is a great deal of kunker associated with it.

In many places near the trap intrusions, the schistose rocks form a breccia cemented with the kunker on the glacis of the outlying range; next to the plain there is a depth of two to three feet of a concretionary limestone imbedding quartz, &c.; it is extremely hard.

In crossing the hills by the Pass, the dip of the rocks which is east on the Dumul side changes to west about two miles beyond the village of Dhonee. The rocks there met with are talcose, and mica-schist, red argillaceous schists, and, lastly, chlorite-slate, in general greatly altered by the intrusion of greenstone. It is among the chlorite-slate hills on the west that the gold is found.

The greenstone has in many places undergone disintegration; and although externally it has merely a dark weathered appearance, yet when struck with the hammer it gives a hollow sound, and on being broken is found to be quite light, having apparently been acted on by an agency quite distinct from that of the atmosphere, whole hills of it being (to the core) quite rotten.

The chlorite-slate is highly quartzose and indurated, and it is difficult occasionally to discriminate between this slate and the igneous rock which has occasionally been ejected between the strata.

The development of iron pyrites is exceedingly great in the gold region; and, were it not that all the conditions on which the large development of the precious metal depends are here found in conjunction with the pyrites, it might be imagined that the small quantity of

gold now found in the nullas in this part of the country was derived from this source,—iron pyrites, as is well known, often yield a small amount of gold.

I have occasionally met with small "pepites" of gold of a pear-shape, and so smooth that at first I thought they must have come from the goldsmith's furnace; but I subsequently met with them in gravel removed from villages, and where it was impossible to conceive that an artificial product of this kind could have found its way.

It is stated that the gold in Australia, when found in small pieces, has this appearance, looking as if it had undergone fusion in a furnace.

PLATE XIII.

Fig. 10.—*Section of part of the Main and Outlying Ranges of the Kupputgood Hills through the Soltoor Pass.*

1. Gneiss and hornblende-schist.	7. Talcose schist and quartz.	13. Trap, and much Iron ore.
2. Spheroidal basalt decomposed.	8. Trap, and breccia of schist.	14, 15, 16. Schists alternating with Trap.
3. Mica-schist with quartz veins.	9. Mica-schist and quartz.	
4. Basalt.	10. Trap, and breccia of schist.	17, 18, 19. Chlorite-slate and trap (greenstone).
5. Mica-schist and quartz.	11. Talcose schist and quartz.	
6. Trap.	12. Mica-slate.	

aa. Main Range of the Kupputgood-red argillaceous slate and schist, siliceous and iron-schists.

bb. Outlying Range, composed of talc and mica schist, red argillaceous schist, siliceous and iron-schist.

cc. Ditto parallel to the above, and composed of the same rocks.

ddd. Red argillaceous schist and slate converted into iron ore.

fff. Argillaceous slates, red and grey, with much iron pyrites in them.

gg. Hills of decomposed slaty greenstone in the chlorite-slate district—Gold Region.

Fig. 11.—*Section at another point.*

a. Granite covered with black soil—Anigeerce.

b. Laterite and red soil.

c. Jaspideous bands, N. by W.

d. Talcose schists.

e. Mica slate, decomposed on the surface.

f. Gneiss, mica-slate, &c., covered with black soil.

12.—*Section at a third point.*

a. This face is completely covered with *débris* of siliceous and iron schist.

b. Is composed of talcose and micaceous schists, but, from large beds of iron-schist, is covered with thin *débris*.

c. Has at (*d*) a band of iron-schist 60 feet thick, then beds of micaceous and talcose slate full of quartz-veins.

e. A low hill having talcose quartz, and hornblende gneiss.

f. Gneiss, mica-slate, hornblende-schist.

Memoir to illustrate a Geological Map of Cutch. By C. W. Grant, Esq., Captain, Bombay Engineers.*

[Read February 22nd, 1837.]

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2. *Sandstone and clay, with beds of coal*—Iron ore, and manufacture of—Coal—Borings for coal—Vegetable impressions—Extent of coal-field—Alum works near Mhurr.
3. *Red sandstone.*
4. *Upper secondary formation*—Description—Relative position with respect to the other strata—Apparent position with respect to the English series—Fossils—General shape of the hills—Manner in which the hills have been formed.
5. *Nummulitic limestone and marl*—Characteristic fossils.
6. *Tertiary strata*—Fossils—Extent of the formation.
7. *Alluvial, or recent deposits*—Land gaining on the sea—Marine forests—Effects of floods.
8. *Volcanic and Trappean rocks*—Evidences of disturbing agents—Distinct periods of Volcanic eruptions—Alternations of basalt with strata of the upper secondary formation—with calcareous grit—with travertin—Dikes of basalt—Extinct volcano—Igneous outbursts.

The Grand Runn.—Natural walls—Successive depositions of marine and fresh-water strata.

Conclusion. Appendix, Description of fossils.

Geographical Position, and Physical Aspect.

The province of Cutch, in the East Indies, is situated between the 22° and 24° of north latitude, and 68° and 70° of east longitude.† It is bounded to the north by the Grand Runn, beyond which is the Thur or Little Desert; to the SW. and south by the Gulf of Cutch and the Indian Ocean; to the east and SE. by the district of Guzerat; and to the NW. by the eastern branch of the Indus and the territory of Sinde. Its extreme length from east to west is about 180 English miles, and its extreme breadth is 50 miles; but in one place it is not more than 15 miles across. It contains about 6,500 square miles, independently of the Grand Runn, which ought, however, to be considered as a part of the

* Reprinted from the Transactions of the Geological Society of London, vol. v. p. 289 (Second Series).

† See Map.

province, and which, including the islands with the portion bounded by the Guzerat coast, occupies an area of at least 9,000 square miles.

Physical Aspect of the Country.—The province is hilly and rocky, with the exception of the part forming the southern coast, which is a dead flat covered with a fine rich soil. Three distinct ranges of hills, having an easterly and westerly direction, may be traced (see Map). The most northern forms an irregular chain bordering the Runn, and, for the greater part, presents to the north a perpendicular cliff surmounting a sloping talus, and to the south an inclined plane. It is composed chiefly of rocks, containing marine remains. The next, called the Charwar range, passes transversely through the centre of the province, and is connected with the former, at its north-western extremity, by a cluster of hills. It consists partly of sandstone containing beds of coal, and partly of a series of strata of slate clay, limestone slate, and slaty sandstone. The third or southern range, is composed entirely of volcanic materials, and has the same direction as the other two; but it is of smaller extent, and a branch of it, striking nearly north and south, passes through the centre of the Charwar range. A number of isolated volcanic hills are also scattered over the plain and in other parts of the province, particularly on the borders of the Runn where is situated the hill called Denodur, the largest in Cutch.

There are no constant streams, the river-courses being merely channels for conveying the periodical floods to the sea, and containing, during the remainder of the year, only detached pools. The banks of these courses are, however, very high and precipitous, and afford excellent sections of the strata through which they pass.

Formations.

I have divided the country into the following eight distinct formations:—

1. Sienite and quartz rock.
2. Sandstone and clay, with beds of coal.
3. Red sandstone.—This formation I have not coloured in the Map, having been unable to trace its boundaries. In mineralogical characters it resembles the new red sandstone of England, and differs materially from No. 2, or the formation which contains the coal.
4. Upper secondary formation, consisting of slate clay, limestone slate, and slaty sandstone, and containing *Ammonites*, with other fossils characteristic of the secondary formations of Europe.
5. Nummulitic limestone and marl.
6. Tertiary strata.

7. Alluvial, or recent deposits.
8. Volcanic and trappean rocks, including all such as bear evident marks of a perfectly igneous origin, as basalt, &c.

These eight divisions, considering the red sandstone as one, represent generally the geological structure of the province, though many minor subdivisions might doubtlessly be made; and the surfaces coloured in the Map must be considered rather as giving a general idea of the extent of the different formations, than as defining correctly the boundaries of each division.

1. Sienite and Quartz Rock.

The only good example of sienite *en masse* is a hill called Calunja, near the town of Nuggur in Parkur, a district in the Thur, and not far from the mouth of the Loonee river. It is not in Cutch Proper; but as it forms part of the northern coast of the Runn, and is in other respects connected with the geology of the province, I have introduced it as one of the formations.

The Calunja hill is a confused heap of light red sienitic rocks, composed of quartz, red or white felspar, and large long crystals of hornblende; the compound being sometimes coarsely grained, and sometimes finely. The base of the main hill is surrounded with small conical mounds, which, at a distance, resemble the huts of a village. On entering the space occupied by these mounds, the hill presents a number of irregular, shattered masses, the sides of which are so steep, and are worn so smooth by the action of the elements, as to be extremely difficult of access. Between these masses the sand lies very deep. It is quite evident that this hill has been violently acted upon by earthquakes.

In the bed of a river near the village of Kooncrea, in the Puchum island, situated in the Grand Runn, I found some masses of precisely similar sienite, which were probably erratic blocks from the Calunja hill; and it will be seen, by referring to the Map, that this island lies nearly in the direction which would be taken by any sudden floods, coming down the Loonee river.

Quartz Rock.—This rock is principally developed in a hill of considerable height near the town of Mhurr, situated towards the western side of the province. The upper part of the hill is entirely composed of it, and huge masses are scattered about the base. A large cleft extends about half way up the western face of the hill, and displays its internal structure, consisting of a centre of quartz rock, surrounded by horizontal strata of loose, quartzose sandstone. The quartz rock varies considerably in character, being sometimes perfectly compact, exceedingly hard, conchoidal in its fracture, and smooth or foliated on the

surface; in other parts it is saccharoidal; occasionally it consists of larger particles, so firmly cemented together that they break with smooth surfaces; some masses, again, have a decidedly granular texture; and one variety is composed of rounded pebbles of quartz of the size of marbles; but in no specimen did I find any other material than pure quartz.

From the extremely fractured appearance of this hill, and from the quantities of basalt lying about, and forming the principal part of some small hills immediately adjoining it, there can be no doubt that it has been subjected to igneous influence; and to the same cause the variety in the texture of the quartz is also probably due, some portions appearing to have been sufficiently fused for its particles to have agglutinated into a solid mass. This opinion may, perhaps, be further strengthened by an examination of the country near the town of Mhurr, distant about one mile and a half, where various dikes of basalt traverse the strata. Similar intermixtures of quartz with basalt occur in a hill called Peaka, from its piebald appearance, not far from Joorun, on the Runn, and nearly opposite the south-west extremity of the Bunnee; also in some low hillocks at the base of the Katrore hill in the Charwar range. At the village of Ghuranee, about ten miles east of Mhurr, a large dike or vein of quartz protrudes from a level plain, and forms a ridge of solid rock about 30 feet in height. Basalt also crops out near the same spot.

2. Sandstone and Clay, with Beds of Coal.

This formation occupies a considerable portion of the country (see Map), and consists of a regularly stratified series of thick beds of sandstone, alternating with slate-clay, which contains, occasionally, bands of ironstone; and where the coal occurs, it is intermixed with blue clay or shale, and a greasy substance resembling fullers' earth. South of the Charwar range, the general dip of the strata is S. by W. and SW., at about one foot in twenty or thirty; but north of that range, the dip varies so much that it is impossible to ascertain the prevailing direction; and the whole series is so broken, and intersected with dikes and dislocations, as to render fruitless all attempts to determine its general strike.

It will be seen by the Map, that the centre of the province is dotted with hills containing igneous rocks; and the disturbed state of the beds, in their vicinity, may easily be conceived. The smaller hills are composed of confused heaps of a very ferruginous sandstone and ironstone, belonging to this formation, and the surface soil is a deep sand. The texture of the strata varies from a coarse, loose sandstone to a compact and extremely hard quartzose grit and conglomerate, cemented by ferruginous matter, some specimens being almost black.

Iron Ore.—In this formation the iron ore smelted for commerce is procured. It is found in different parts of the country, but has been principally extracted near the town of Doodye, opposite the SE. termination of the Bunnee. It there occurs in small lumps, which are of a spongiform texture, small specific gravity, and are very frangible. The natives, however, value this variety more than the heavier, from its yielding with greater ease to their imperfect means of smelting.

Manufacture of Iron.—In extracting the metal, layers of very small pieces are disposed alternately with others of charcoal, in a rude open furnace, and exposed to the blast of two small bellows made of sheep-skins. The metal, when fused, falls into a hole at the bottom of the furnace, whence it is transferred to an enclosed furnace, and subjected to similar blasts, until brought to a white heat, when it is taken out and beaten into a bar. No flux of any kind is used. A considerable quantity of iron was, at one time, made from a totally different description of ore, found near the village of Punundrow, in a plain which extends to the sea or eastern mouth of the Indus. This plain is bounded to the south by low hills covered with fragments of basalt, being outliers of a basaltic range farther to the south-east. The surface of the plain is composed of a fine smooth gravel, composed of comminuted particles of iron ore, and has every appearance of having been, at no distant period, covered with water. The iron ore is found near the surface of the low hills above mentioned, in small tabular fragments imbedded in a purple-coloured earth ; and those pieces are selected, which give a bright streak on being struck by a pointed instrument. Externally the ore is of a purple colour, and internally presents small dark blue fibres, arranged at right angles to the surface of the specimen. In another place a variety occurs, which resembles small fragments of tile, but has the same internal structure. It is very hard, and of considerable specific gravity ; and is said by the natives to have yielded a much greater per centage and much better iron than the ore found at Doodye ; but the manufacture of it has been suspended, owing partly to the scarcity of fuel, and partly to English iron being procured at a cheaper rate, as well as in much more convenient forms.

Coal.—Coal has been found in this formation in various places, but not in beds sufficiently thick to be worth working. It was first discovered in the bank of a river near the city of Bhooj, forming a bed about 18 inches thick, and associated with strata of sandstone and blue clay, the dip being, to the eastward, one foot in twenty. This bed was worked for some time, and considerable quantities of its produce were sent to Bombay, but the quality was bad, being very slaty and containing a large proportion of incombustible matter. Attempts were afterwards made to discover coal in other parts of the province ; and

although various beds were met with, they were too thin to be of any value. This search was carried on principally to the south of the Charwar range, a few miles from the town and fort of Secsaghud. One bed was found of a very good quality, but only nine inches thick. It consisted of masses composed of small cubical pieces, which soiled the fingers very much, had not the slightest appearance of a lignite, and ignited quickly, burning with a bright flame, and leaving a small residuum, but it would not cake. It was found, on trial, to get up the steam of an engine-boiler very well and quickly, but a much larger quantity was required than of English coal, owing, partly, to its breaking into so small fragments as to fall through the bars of the grate.

Borings for Coal.—A boring for coal was made near this bed; and although 270 feet of sandstone and blue clay were penetrated, no coal was found. A similar attempt was made six miles further to the eastward, and to the depth of 191 feet, but with no better success; and similar researches were made in one or two other places. The second trial passed through a regularly alternating series of sandstone and blue clay. Some of the sandstones were so extremely hard (being composed of quartzose particles cemented by ferruginous matter) as to be almost impenetrable. A jumper, worked by a lever-bar, making eighteen strokes in a minute, penetrated, after eight hours' work only, from 1½ to 2 inches. Other specimens of sandstone varied both in hardness and quality; and at a depth of 190 feet, a bed of white, pure quartzose sand was entered, when water immediately rushed to the surface, and continued to flow in such quantities as to stop the work. The shale was of a very dark blue when first brought up, but it lost the greater part of its colour after exposure to the sun. Iron ore and iron pyrites were found. All the banks of the rivers in the neighbourhood present strata of sandstone and slate-clay, with bands of ironstone, and, in places, thin beds of coal. The general dip is to the south-west, about one foot in twenty; but the strata are greatly shattered and disloeated by dikes, slips, and hitches.

Vegetable Impressions.—The slate-clay, and, in some cases, the sandstone, contained numerous impressions of ferns and reeds,* occasionally of a large size. One specimen, which was flattened, was four inches in breadth, and the outer surface was carbonised, but the interior was filled with sand; this was generally the case, though other specimens were carbonised throughout, and some were mere impressions. In digging wells within the limits in which they occur, coal was frequently found, but always in thin beds; and some of it ought more properly to be called lignite.

Extent of Coal-field.—The coal-field, if it may so be termed, is bounded

* Plate XV.

to the north by the upper secondary or laminated slate-clay and limestone slate formation; and to the south it is cut off abruptly by a low range of volcanic and trap hills. I could not ascertain whether it had ever been covered by any conformable, stratified deposits. Thin beds of coal have been found in various other parts of the formation. The general structure of this series of strata, the quality of some of the coal, the nature of the sandstone and slate-clay, the impressions and remains of reeds, ferns, &c., the bands of ironstone, the dislocations by dikes, slips, &c., all bear an analogy to the coal-fields of England; but I am inclined, from the vegetable remains, to consider this deposit an equivalent of the oolitic coal of England, and not of the regular carboniferous system.

Alum Works near Mhurr.

The ground on which Mhurr is built consists of high, irregular banks of marl of every variety of colour, but in a most confused and shattered state. It is surrounded on three sides by steep hills, forming a kind of amphitheatre; and nothing can be more desolate than its appearance. North of the town is a high table-land, which extends to some hills about one mile and a half distant. It is composed, near the base, of a ferruginous quartzose sandstone, on which the variegated marls rest; the latter being covered, in many places, with a bed of coarse gravelly detritus, six or eight feet thick. Imbedded in this gravel are some very large masses of basalt, and of a very hard, black stone, composed of grains of quartz cemented by an almost black oxide. They are cut into mill-stones for grinding flour. The whole are evidently boulders from the hills to the northward, which were mentioned in the first part of this memoir, as consisting of quartz and basalt. This plain terminates, to the southward, in a high bank overlooking the town, and intersected in one part by a large dike of spheroidal basalt, which has apparently so indurated the strata of variegated marl in its vicinity as to permit them to be quarried for building. A large quantity of alum is made at this place, and exported to different parts of India.

Manufacture.—The shale from which alum is obtained forms beds in the variegated marl; and in a kind of blue clay. Long galleries are cut for the purpose of extracting it; but so plentiful is the supply, that no means are taken to support them, and they generally fall in during the rainy season. The manner in which the alum is prepared is very simple. The earth is exposed in heaps to the sun and air for about five months, during which it burns spontaneously. It is next laid out in little beds similar to those of a field prepared for irrigation, and it is watered by a small stream for ten or fifteen days, by which time the aluminous matter accumulates into semicrystalline plates. This

substance is boiled in water for about seven hours; after which, a third, or one half, by weight, of potash is added, and it is again boiled for a few hours, according to the strength of the ley. It is then poured into large open vessels, where, after settling for some time, it is washed, and the liquid drawn off, leaving an impure crystalline sediment. This is onee more boiled, and when it arrives at a proper state, which is learned by practice, it is poured into large earthen vessels with a small mouth, and sunk into the ground to prevent their breaking. After a time, the vessels are dug out, broken to pieces, and a lump of pure alum extracted. Six or eight measures by weight of alum are produced from ten measures of the substance from the irrigated beds, and four or five measures of potash. It is not so much esteemed in the Bombay market as that brought from China, on account of its yellow tinge.

Some of the marls resemble chalk, being white, and soiling the fingers; and some are very calcareous, whilst other varieties scarcely effervesce with diluted muriatic acid. In one mass I found a very minute specimen of *Buccinum pumilum* (sp. n. Pl. XVII. fig. 1). These marls also occur of every variety of colour as well as texture; some of them consisting of innumerable thin laminæ curiously twisted and arranged in the most intricate manner; and others of a kind of breccia, composed of small broken portions of marls. Several dikes of basalt cut through these beds; the whole presenting a most confused assemblage, partly due to natural causes, and partly to the numerous mines which have fallen in. One of the banks has been burning spontaneously for several years, in a similar manner to that at Ruttrea, and apparently from the same cause. The exact geological position of these marls I could not determine.

3.—Red Sandstone.

I have mentioned a red sandstone formation, which may be described now. It occurs to the southward of the coal series, and is separated from it by a low range of hills about six miles broad, composed partly of basaltic rocks, and partly of a variety of porphyry. This sandstone is regularly stratified, and has the same dip and inclination as the sandstone and coal series, but differs very materially from it, in being much softer, generally finer-grained, of a vast variety of colours, and by containing no organic remains. Associated with the sandstone are beds of clay, varying in colour from purple to deep red. One of the beds is aluminous, and has been burning spontaneously for a long period. The smoke issues from a deep crevice in the bank, and the fumes are highly sulphureous. A stick thrust into the crevice soon ignites, and the whole bank has a burnt appearance; the red clay, which rests immediately upon the stratum, having been converted into a perfect brick, and the

other variegated clays having been variously acted on. Although this bed would yield a large per centage of sulphate of alumina, it has never been worked. The strata dip at an acute angle to the south, and are covered, in that direction, by beds of gravel, succeeded by others of sand and soil, which extend to the sea.

4.—Laminated Series, or Upper Secondary Formation.

Alternating strata of slate-clay, limestone-slate, and occasionally slaty sandstone, constitute this formation. The more calcareous beds are very hard and compact, whilst some of the others are very earthy and friable. In many of the calcareous slabs, the upper and under surfaces are argillaceous, hard, and compact, but the centre is a grey limestone, which takes a good polish, and might be used for lithography. The slate-clay is of a dark blue colour, and generally peels in thin flakes, leaving a flat, lenticular nodule or centre. In many places, vast thicknesses of this laminated slate-clay occur, without the least admixture of the sandstone-slate, whilst in others the latter alternates very often with it.

The beds being horizontal, except where they have been disturbed, the formation occupies considerable tracts; and where it rises into hills it is generally capped by a thick bed, either of coarse, soft sandstone, as in the Ghàts of the Charwar range, the Bhooda hill (near Bhooj), the Jarra (near the Indus), and other hills; or of a very compact, hard, crystalline sandstone, with a conchoidal fracture, as in the Chuppal hills, the Jarra, and in other places, including the natural walls of the Runn, described in a subsequent part.

Relative Position with respect to the other Strata.—I searched diligently to find the relative position of this formation distinctly defined, but in vain, as, at its apparent junction with other beds, the whole of the strata were broken up, and so confused as to baffle every attempt to ascertain the boundary. I am induced, however, to believe that it occupies hollows in the sandstone and coal formation, or abuts against it. It cannot underlie that series, because its strata are always *horizontal*, except where locally disturbed; while the beds of sandstone and coal are as invariably inclined at a considerable angle, and are everywhere intersected with dikes, slips, and other dislocations, from which the upper secondary strata are generally free. In one instance the formation evidently occupied a hollow in the coal sandstone.

In many places it appears to abut against the sandstone, occupying large tracts which may, at some period, have been covered by beds of that formation, subsequently washed away. From what has been stated above, it is at all events newer than the coal beds; and this conclusion is also borne out by its imbedded fossils.

Apparent Position with respect to the English Series.—In its mineralo-

gical character and general appearance, this formation greatly resembles the English lias; but its fossils have been found, after a careful examination by Mr. James Sowerby, to assimilate very closely to those of the oolitic beds, and a very few belonging to the green sand.

Fossils.—Of the fossils found in these beds, the Ammonites are the most characteristic, occurring in vast quantities, particularly in some hills bordering the Runn. Of the eleven species which I collected, eight are unknown to Mr. James Sowerby, to whom I am entirely indebted for all my information regarding them. (See Plates XV. XVI. and XVII.) Of the other three species, one so closely agrees with *A. Herveyii* (Plate XVII. fig. 5) of the English cornbrash, that he is induced to consider it only a variety of that species; another, in the outer whorl (Plate XVII. fig. 13), resembles *A. perarmatus* of the coral rag, but differs in the structure of the inner whorls; and the third, of which there is only one imperfect specimen (Plate XVII. fig. 12), is like *A. corrugatus* of the inferior oolite of England. They generally vary in diameter, from three to five inches: the largest I found being eight inches. It was imbedded in a mass of gold-coloured oolite. The genus next abundant is the Terebratula. Of the seven species collected by me, five bear so close an analogy to the *T. biplicata*, *T. dimidiata*, *T. sella*, *T. intermedia*, and *T. concinna* of the green sand and oolitic series, that it has been found impossible to consider them distinct species. The Trigonias are numerous, though confined to two species, one of which differs so very little from *T. costata* of the lower oolites of England, that Mr. Sowerby considers it only a variety of that fossil. The genus *Pholadomya* also abounds, but the specimens are generally broken. Of the three species I collected, Mr. Sowerby has not been able to establish an identity with any known Pholadomya in England, although there is a general resemblance to the oolitic and lias fossils. I found two species of Belemnites, one of which resembles *B. canaliculatus* of the inferior oolite; the other is not determinable. Of the species of oysters, one resembles the *Ostrea Marshii* (see Plate XVI. fig. 9) of the English cornbrash. I found it in a bank high up the Katrore hill, in the Charwar range, in friable, laminated strata of slate-clay and sandstone slate, associated with Ammonites of the same description as those at Charee and along the Runn.* I did not find a single specimen of a Gryphæa, although numbers of the genus have been collected from this province. Some crinoidal stems, which I collected from the same localities (see Plate XVII. figs. 14, 15, 16), resemble those of a species found in the

* At the base of these hills, and forming the immediate borders of the Runn, fossil shells are found of a very different description, among which I may enumerate *Cardium, Pecten, Corbula, Venus, Globulus,* and vast quantities of *Turritella;* which last form large masses of rock protruding every here and there above the bed of the Runn.

mountain limestone; but as the fossils above enumerated characterise the middle series of the English upper secondary rocks, fossils belonging to so much older a formation can hardly be associated with them. These crinoidal remains, therefore, probably belong to an undescribed species. The only fossil bone which I discovered, Messrs. Clift and Owen consider to be a caudal vertebra of a Saurion. This determination is, however, very interesting, as it shows how widely these animals were distributed; being, in this distant country, also associated with the same mollusca (one valve of a *Trigonia costata* is imbedded in the mass containing the bone) as accompany their remains in the English strata.

In the Appendix to this paper I have given a complete and systematic list of all these fossils, stating the localities where I collected them.

General Shape of the Hills belonging to this Formation.—Many of the hills in Cutch present, on the north side, a perpendicular cliff surmounting a sloping talus, and on the south an inclined plane; and they owe this peculiar outline to their being composed of a base of laminated clay or sandstone, capped by a thick bed of coarse and brittle sandstone. This is particularly the case in the Jarra hill, and the hills of Hubbye, Lodye, and Roha-ké-Koss, near the village of Joorun, on the Runn; also those of the Puchum and Khureer islands in the Runn, particularly the latter; likewise those near Beyla, at the north-eastern extremity of the province, and many others. The Katrore hill, forming the eastern extremity of the Charwar range, belongs to this formation, and, therefore, differs materially from the greater part of the range, which is composed principally of sandstone, except in the portion opposite Bhooj, where this laminated series also occurs. The strata being principally horizontal, the hills have a conical form.

It is a curious circumstance, that, in the same group, some of the hills of the laminated strata have a thick capping of sandstone, whilst an immediately adjoining peak, of equal height, has none. I conceive the thick beds of the sandstone once covered the whole surface, and that on their upheavement they broke into masses, which have been since denuded from some of the hills, the *débris* forming the deep sandy plain around Bhooj.

In the hill of Jogé-ki-bit, near Nurra, on the Runn, the beds dip from 40° to 50° to the north, and alternate three times with basalt. The strata vary greatly in character, some of them being very hard and crystalline, particularly those containing calcareous matter; whilst other parts of the series, immediately adjoining, are very friable and earthy. Some of the schists assume the character of a roofing-slate, and others are only soft, laminated blue clay.

A cluster of hills, occupying a surface of three or four square miles to the north-west of the city of Bhooj, called the Bhoodha hills, also

belongs to this formation, being composed of slate-clay, tabular sandstone, and limestone slate, in many parts assuming a very friable, earthy texture, and frequently capped with thick beds of coarse, soft sandstone. The strata are often horizontal; in which case the hills are conical; but in many instances the beds incline at a considerable angle; and the hills assume, when capped by the sandstone, the usual form of an abrupt escarpment, with a long inclined opposite side. They are intersected by numerous ravines and nullas; the looseness of the soil, and peculiar tabular construction of the strata, offering a very slight resistance to the action of the rains. The Chuppal hills, between Guranee and Nurra, in the north-western division of the province, afford another example of the elevation of these strata into hills. They consist of beds of a very earthy and friable description, covered by a thick stratum of hard crystalline sandstone, slightly calcareous; and the lower part forming a sloping talus, capped by the hard rock, in masses 20 feet thick; they appear as if they were surmounted by old ruins or turrets.

Manner in which the Hills have been formed.—From an attentive examination of these hills, I am led to infer that they have all been uplifted by a movement which proceeded from below; the laminated series having yielded to the upheaving power, and the loose brittle sandstone having broken off abruptly. That this has been the case with the minor ridges, and what I may term the *natural walls* in the Runn, described in treating upon that district, there can be no doubt, as I have found them at angles, varying from a few degrees above the horizontal position to the vertical, and even turned over beyond that point.

That these beds have been disturbed and broken through by igneous agents is quite evident from the dikes of basalt, which occasionally intersect them.

5.—Nummulitic Limestone and Marl.

Although the imbedded fossils of the Nummulitic group resemble those of some tertiary beds of England and France, still the strata of which it consists differ so totally in mineralogical character and general appearance from any of the other formations in Cutch, that it deserves a separate notice. It is bounded partly by the second or sandstone and coal formation, partly by beds which I have coloured as tertiary, and partly by the alluvial banks of the eastern branch of the Indus, extending from Luckput to a plain between the villages of Wagé-ké-Pudda and Eyeraio, about thirty miles to the southward. It consists of a mass of small Nummulites mixed with Fascicolites; and some of the river banks present a perpendicular section of solid rock, from 60 to 70 feet in height, entirely composed of these small fossils agglutinated together,

and varied only by a species of Orbitolites, frequently bent into a saddle shape. This stone has much the appearance of chalk, and the beds are horizontal, except where they have been disturbed. In some parts, however, it is much harder, particularly near the town of Luckput, where it is quarried as a building stone, and is also burnt for lime. The surface-soil is entirely composed of the small fossils lying loose, and generally known by the name of Luckput sixpences.

The beds of Nummulitic limestone on which Luckput stands have been affected in a manner deserving of notice. (Plate XIV. fig 1.)

The high ground to the east of the town sends off three parallel ridges to the westward, ranging nearly east and west. On the two northernmost of these ridges, the north and south walls of the fort of Luckput are built; whilst the southernmost lies at a distance of about 200 yards from the south wall. A kind of valley runs through the town, ending, at its western side, in a swamp, which is crossed by the western wall of the fort. A cut through the northern ridge exposes a very good section of the nummulitic stone, dipping 40° to the north; whilst in a similar cut through the southern ridge, made for the purpose of connecting two tanks, the same beds dip from 40° to 50° due south. In the centre ridge the section is not quite so perfect, but the beds are nearly, if not truly, horizontal, forming an anticlinal axis to the other two.

This elevated tract of the nummulitic limestone extends only three miles to the eastward of Luckput, the ground there descending abruptly into a plain, composed of various clays, a coarse ferruginous stone and sandstone, with quantities of selenite scattered about, the whole presenting a confused appearance, as if it had been the site of an igneous outburst. Patches of ground, every here and there, have also an altered appearance, and are covered with small fragments of igneous rock. The plain is bounded to the south by a low range of basaltic hills. From Luckput southward to the village of Punundrow, the same nummulitic rock continues, but varies in hardness from a compact limestone to a white marl. It is also very well exposed between the villages of Eyeraio and Wagé-ké-Pudda, at the southern limits of the formation. To the SW. of Eyeraio is a plain, composed of a white calcareous marl, and flanked to the south by a low range of hills of the same material, sending off into the plain numerous small projections, with rounded terminations precisely like headlands. Numerous isolated hillocks, or high banks, with sides worn in the same way, and resembling islands, are scattered about the plain, and the whole surface looks as if it had only lately been deserted by water, or as if a violent flood had swept over it. The banks of the small nullas, which intersect the plain, are composed of gravel, containing rounded masses of a variety of the calcareous marl. Advancing westward, the ground rises a little, and the

surface consists of a hard rock, which contains oysters and other bivalves, whilst in some places large patches are entirely composed of silicified corals. I also found in this place fragments of fossil bone, said by Messrs. Clift and Owen to be parts of rib-bones, like those of the *Manatus*, but flatter. To the north, this plain is bounded by a river, the perpendicular banks of which, 60 or 70 feet in height, consist entirely of nummulitic marl, capped by a thin stratum of gravel. In one part, the bed of the river is subjected to the action of a small stream of water, so strongly impregnated with saline ingredients, that large lumps of salt are formed in the hollows worn in the rock, which here assumes the character of a hard limestone, probably in part due to the quality of the water that passes over it. The beds are horizontal, except where they have been disturbed and shattered.

Characteristic Fossils.—The most characteristic fossils of this formation, next to the Nummulites and Fascicolites, are Echini, Galerites, Clypeasters, and Spatangi. The species of Echini and Galerites are all new. A Clypeaster resembles *C. affinis* of the sandy marl of Barbant; and a Spatangus, the *S. Bucklandii* of the marly chalk of Westphalia; while another species agrees with the *Spatangus acuminatus* of the tertiary deposits of Dusseldorf. The other fossils consist of species of Tellina, Astarte, Cardium, Arca, Pectunculus, Pecten, Nucula, Ostrea, Cerithium, Turbinellus, Globulus, and Seraphe. (See Plate XVIII.) The Turbinella abounds, and is often very large. In the bed of the river above described I found large blocks composed entirely of small oysters, similar to *Ostrea Flabellulum*, but more regularly and finely striated.

6.—Tertiary Strata.

I have called all that portion of the province *tertiary* which is composed of rocks, containing fossils belonging to this period. It consists principally of a hard argillaceous grit, interspersed with fossil shells, and covered by beds of pebbles or conglomerate. Some portions of this conglomerate are very coarse, and constituted of rolled or boulder stones loosely connected; whilst other portions are sufficiently indurated to be used as a building stone. A calcareous grit, which soils the fingers like chalk, also occurs in patches, and contains innumerable small shells. It is used for building, and is burnt for lime. The beds are horizontal, and the surface of the country is generally covered with a fine rich soil.

At the village of Soomrow, about ten miles north-east of the fort and harbour of Juckow, on the south-western coast (see Map), the banks of a broad river-bed are composed partly of a loose gravelly soil, and partly of a very hard, compact, calcareous rock, full of shells, and burnt for lime; and below this rock is a coralline limestone. The river-

bed, in some places, is nearly a mile across, the banks being cut into ledges or steps, whilst numerous small hillocks, or high banks of gravel and clay, stand isolated in its middle. Only a small stream now winds from shore to shore. One part of the northern bank rises into a small hill, the surface of which is composed of the same hard, compact, shelly rock as that which is found even with the bed of the river. For some distance north of this spot, the ground is also high, and cut into innumerable ravines; and there are breaks in the surface, as well as circular hollows, or large, deep pits. The natives have a tradition, that an earthquake occurred at this spot, some centuries since, during a severe battle between the Sindians and the natives of Cutch. The raised position of the shelly rock, and the peculiarly rent and broken appearance of the ground, indicate some convulsive movement; and it should be noticed, that, as all the beds are horizontal, those forming the hill cannot be an unbroken continuation of those in the banks of the river.

This formation continues a few miles further to the northward, where it abuts against the nummulitic beds.

In many places towards its northern limits, it rises into hills, and considerable tracts of high, undulating country; the loftier portions consisting invariably of hard, shelly rock, including large patches, of one or two acres in extent, of silicified corals; and the lower parts, or intervening spaces, of a loose gravel or clay, equally full of organic remains. Some parts of this district, particularly that near the village of Kotra, have a very remarkable appearance, as if they had been subjected to a violent flood, which had washed away the surface-soil to a depth of 30 or 40 feet, leaving a broad, shallow valley, two or three miles across, with numerous isolated and rounded bluff hills of gravel, scattered about its bed. The banks, or bounding lines, consist of low hills, cut into innumerable small ravines; the whole being composed of the same shelly rock, and gravel, and clay, as above described.

The fossil shells found in this district occur often in beds, consisting of a single species. One of the hillocks, above described, is about 60 yards long by 20 broad, and 15 feet in height, and is entirely covered with *Ostrea callifera*, lying loosely on a gravelly soil, or cemented into a solid rock. The highest part of the table-land in one place, near the village of Kotra, is also composed solely of oysters, forming a very hard rock or limestone; other isolated banks are completely covered with what appears to be a species of large Serpula, or else fragments of coral. Numerous other fossils are found, either lying loose or imbedded in the rock, and consist of species of Lucina, Venus, Cardium, Pecten, Ostrea, Turritella, and Clypeaster. The Turritellæ are imperfect, but particularly numerous.

This flat valley or broad river-bed (for a small stream still winds through it) continues to the hills surrounding the town of Mhurr, spreading, in places, into lake-basins, all of the same description as above detailed; but, a short distance south of the Mhurr hills, its course is cut across by a dike of very compact basalt, of perfectly columnar structure; each face of the polygons being about two feet in breadth. This basalt forms both banks of the river for 50 or 60 yards, and to the height of 20 or 25 feet; the bed of the river being also formed of sections of the columns. The clay through which the basalt passes is hard, and of a brick red; and quantities of iron ore, of a spongiform texture, are scattered about.

The southern base of the Mhurr hills is now approached, and presents a most confused appearance, the country at their foot being shattered in all directions. It is impossible to conceive ground in a more disturbed state. The banks and ridges, varying from 20 to 60 feet in height, are partly composed of coarse, calcareous grit full of the marine shells already enumerated, and partly of a blood-red coloured clay, which has apparently been altered by a trap dike. One bank exposes a section, 60 to 70 feet high, of horizontal layers of gravel, clay, shelly rock, and iron clay, which in one spot appear to have fallen in bodily, dipping abruptly from both sides to a point.

Fossils.—The principal deposit of fossil shells which came under my inspection, was at the village of Shoomrow, just described. The specimens which I collected have been examined by Mr. James Sowerby, and found to consist of 33 known genera. Of the 57 species belonging to these genera, 47 are new, 6 are known, and 4 are doubtful. (Plates XIX. and XX.) The most numerous among the univalves belong to the genera Mitra and Voluta: there are also great quantities of the genera Cerithium and Terebra; some of the latter being very beautifully marked. The genera Solarium, Conus, and Strombus also abound. Among the bivalves, the Pectens are most numerous; and among the Radiata are great numbers of Clypeaster. Most of the fossils which I collected, either lay loosely on the gravelly bank, or were cemented into large tabular slabs of rock.

I was informed by the natives that, about the year 1834, great quantities of large fossil shells, called by the country people *Sonk* or *Conk*, being a species of Turbinella, were found in a landcrack, in a field about two miles from this spot; and so perfect, that they were given to the priests of the different temples in the neighbourhood, who, by inserting a metal tube into the apex of the shell, converted them into horns, to call the devout to prayer. I could not, however, find any when I visited the spot, the crack having been filled up by subsequent floods.

Extent of the Tertiary Formation.—These tertiary beds reach, in one place, to the town of Mhurr, a distance of thirty miles from the sea, and extend in a belt of, perhaps, a third of that breadth, throughout the whole southern coast of the province. A narrow line should also be drawn along the borders of the Runn, and around the islands in it, as the fossils, found on the immediate shores, belong to the tertiary period.

7.—Alluvial or Recent Deposits.

The part coloured as alluvial in the Map consists entirely of plains covered with soil, evidently detritus which has been washed from the hills, or of land recovered from the sea by the blowing up of sand. The whole of the province south of the volcanic range (see Map) might be considered alluvial; the surface being composed of a thick soil, formed by the rapid decomposition of the basaltic or igneous hills; but as the banks of the rivers contain tertiary shells, I have thought it better to colour the district as consisting of rocks of that age. The boundary between the tertiary and alluvial districts must, therefore, be considered partly imaginary, as I have thought it more correct to give a general outline, than to mark, with apparent minuteness, limits, which my examination of the district did not enable me to ascertain.

Land gaining on the Sea.—In many places along the coast, where there are ridges of sand, the land gains upon the sea. These dunes are constantly increasing, from the particles blown up by the sea-breezes, or the south-west winds, which prevail during so great a portion of the year; and the ridges frequently occur in double rows, occupying a considerable breadth, and varying from 50 to 100 feet in height. During strong winds the whole appear to be in motion, from the sand drifting along their surfaces.

At Mandavee, the principal seaport in Cutch, is a ruin on a spot called the Old Bunder, or Quay. It is now about three miles inland, and is situated on the bank of the river, which flows into the sea near the present town; but at the time when this old quay was in use, the town must have been some distance from the present shore. A small temple, built upon a rock, now in the middle of the town, is said to have been at that time also in the sea. Even now, a considerable space, composed of loose sand and sand-hills, intervenes between the town and the sea; and the distance is continually increasing, owing to the quantity of sandy detritus brought down by the river during the periodical floods, and washed back by the sea in the dry season. A bar is also thus formed across the mouth of the river, and the position of it varies so much, and so often, as to render the entrance to the river very difficult. Even boatmen belonging to the port, who have been absent a few months, cannot pilot their vessels in. During very dry seasons, this

bar increases to so great a degree as almost to block up the entrance entirely; and the laden boats always strand upon it at high water, their cargoes being carried away by carts when the tide is out.

At Moondrah, Budraseer, and other seaports up the Gulf of Cutch (see Map), the land also gains upon the sea, rendering necessary the frequent removal, farther seaward, of the quays or landing-places. Where rivers enter the gulf, this increase of land at their mouths is easily understood, as the sea, for nine months of the year, washes back the sandy detritus accumulated by the river at its delta during the periodical floods. Where rivers flow all the year round, they may be enabled to keep a channel through the deltas constantly free; but when the stream is inert during three-fourths of the year, and the wind and sea are continually at work, the case must be very different.

Marine Forests.—The same operation is in progress at places separated from the main waters of the gulf by small creeks.

Some of these inlets penetrate six or seven miles from the coast through a tract covered for miles in extent with shrubs. At low water, these plants are exposed to their roots; but at high tides merely their upper branches are visible, so that the boats sail through a marine forest, the sails and yards frequently brushing against the boughs of the trees. The growth of these shrubs is so rapid that the sailors have very often to force their boats through the upper branches, particularly at the various angles of the very tortuous creeks, when they wish to save a tack, and the wind is scant. The stems and branches of the trees are covered with Crustacea and Mollusca, whilst numerous water-fowl occupy the higher branches; the whole presenting a most curious picture. That the land should gain on the sea, in these places also, is very natural, as, during the monsoons, when the numerous small streams convey their muddy alluvium into the gulf, the roots and stems of the shrubs act as a filter, and the water passing slowly between them, a great portion of the earthy matter is precipitated; a portion also adhering to the stems.

Effects of Floods.—Considerable damage is frequently done by the periodical floods, which, from the peculiar hilly structure of the country, sometimes rush down with a force that carries all things before them.

In August 1834, the rains were very violent and long continued, and did considerable damage. The river which flows past Nurra, and through the flat, from six to eight miles broad, which extends from the town to the Runn, brought down so much alluvium as to cover with a fine soil a surface of 150 pragas, or nearly 1,000 acres of land. This tract had been sunk by the earthquake of 1819 so nearly to a level with the Runn, as to have remained unfit for cultivation. On the opposite side of the province, at a village called Kundagra, not far from Mandavee,

50 pragas or 300 acres of soil were entirely washed away, leaving a bare sandy surface, similar to the bed of a river; and not far from the same spot, half a small village, with a quantity of land, was swept bodily into the sea; large trees being uprooted and carried down by the flood. At Pheraudee, 12 miles NE. from Mandavee, at Mandavee, and many other places, great devastations are said to have been produced. A few similar inundations would alter the features of the country, consisting of such abrupt hills and loose surface-soil.

8.—Volcanic and Trappean Rocks.

The district coloured in the Map as composed of volcanic and trappean rocks (see Map) is one of the principal features in the geology of Cutch, not only from the space it occupies, but from the phenomena which it present.

The igneous origin of trap being acknowledged, I shall always speak of it and lava under the comprehensive term of igneous rocks, as in composition they differ only in the proportions of hornblende, felspar, and augite, and as they all appear to have originated in the same cause, and to have equally disturbed or affected the neighbouring strata. But there appears to be a very marked distinction between those rocks which have been in fusion below the surface, and subsequently forced up, and those sedimentary formations, which have an altered appearance, and have been evidently subjected to violent heat since they were deposited in their present position. The latter rocks, however, bear a very small proportion to the former. The part coloured as volcanic shows the principal theatre of the outbursts; but to mark on the Map every spot where traces of igneous action are observable, it would be necessary to dot over the whole of the secondary formations.

Evidence of the disturbing power of Igneous Agents.—It is impossible to desire clearer evidence of the disturbing power of igneous agents than is developed in Cutch. The shattered appearance of the country in some places, the upraised hills in others, with the igneous rock or moving agent, either directly under them, or immediately in front of the outcrop of their strata; the angles to which the beds have been raised varying from a gentle, unfractured slope to the most complete dislocations; the vast variety in the composition of the igneous matter, from the most loose and clay-like form to the most compact and perfect columnar basalt; the crater-like shape and construction of some of the hills, from which large lava or basaltic streams can be traced, prove the igneous origin of these rocks, and the vast effects which they have produced on the general appearance of the country. Moreover, it is not necessary that the igneous matter should be on every occasion apparent; as, where we find a large mass of basalt which has evidently

come from below, lying on a plain, behind a hill presenting a bluff cliff towards the igneous rocks, and the strata sloping sharply from them, the conclusion is obvious, that the hill must have been raised by the outburst of the volcanic matter; and it is equally just to infer, that, in its passage from below, it must have disturbed, more or less, the various beds through which it passed; and therefore, that the form of many hills may be owing to a latent exercise of this power, even where no traces of the igneous matter are visible near the surface, or near the raised strata. That the greater number of these igneous rocks have been forced up, and are not portions of lava streams which have flowed from volcanos, is very evident, from the manner in which the superimposed strata are affected by them.

In a preceding part of the paper I have described a hill of quartz rock near Mhurr, and shown that its strata have been violently disturbed; and I have also inferred, from the nature of the rock, that its characters are due to grains of sand having been agglutinated by volcanic heat. In detailing the phenomena presented by the second formation, I have shown that its strata have been also subject to great dislocations.

The following sketch presents an example of a large dike of basalt which has cut through the strata in the river near Jaumtra, and thrown them off in opposite directions. (Pl. XIV. fig. 2.)

In describing the upper secondary formation, I have stated that I conceive the hills owe their outline, presenting to the north an abrupt escarpment resting on a slope, and to the south an inclined plane, to the agency of volcanic forces. In the Karee river, near Bhooj, these beds have been disturbed to an extent which defies representation. Near the village of Jarra, on the borders of the Runn, a bank affords a good example of the manner in which this upheaving power has acted. The laminated beds (upper secondary formation), being of a loose earthy character, have yielded to the disturbing agent; whilst the overlying compact stone has broken short off, and presents a wall of rock, split by such perfectly vertical lines, that at first sight I thought the stone was columnar.*

The range of Roha-ké-Koss, composed of beds of the fourth or upper secondary formation, is a good example of disturbing action. It is situated between the villages of Joorun and Lodye, on the borders of the Runn, and extends nearly east and west for eight miles, presenting, to the north, a perpendicular cliff of sandstone, which rests on a sloping talus of laminated sandstone and slate-clay, and dipping at a high angle to the southward. About three quarters of a mile from this main range, and parallel to it, is a ridge of smaller hills, consisting principally of basalt, intermixed, in some places, with the same sandstone

* Pl. XIV. fig. 3.—*Bank near Jarra.*—*a*, Laminated series; *b*, Compact sandstone.

as that of the main hill; and which, in the banks of the nullas at its base, overlies the laminated strata. The space between the two ridges is composed of large broken masses of sandstone, covered by a thick bed of gravel, evidently the detritus of the hills. In this instance, the strata of the Koss range dip towards the south; and, at a short distance to the north of it, we find a mass of basaltic or igneous matter, which probably raised the hills in its passage up, and established itself at their foot. Large basaltic dikes, disturbing the strata through which they pass, are observable in many of the river banks in the immediate neighbourhood.

The beds of nummulitic limestone, on which Luckput stands, present, as before stated (p. 415), most decided marks of elevatory movements, consisting of a central platform of horizontal strata, with inclined beds on the flanks.

Another most striking example of the effects of igneous action in upraising hills, occurs in the nummulitic limestone, near the village of Punundrow; and the phenomena are so strongly marked that they deserve a detailed description.

On leaving the village of Korah, in the north-west department of the province, and proceeding westward, a range of hills is entered, of small altitude, but covering a considerable area. It is composed of a confused assemblage of basaltic cones in broken columns, or rather of a number of sugar-loaf-shaped masses piled one on the other. The surface of the hills is covered with fragments of a hard greenstone, the crystals of felspar being numerous. The perpendicular banks of the nullas and ravines which intersect this range, present, in some places, entire sections of the columnar basalt; whilst others consist of a friable, sandy clay, disposed in horizontal, thinly laminated strata of every shade of black, red, and yellow, to white; and associated with it is a beautiful purple loam. The basalt sometimes overlies these beds, sometimes forms dikes in them; and one side of the ravine frequently consists of this variegated loam, and the opposite of basaltic pillars. In many places the ground has an altered appearance; the ironstone, of which large quantities are lying about, appearing partially fused, and the clays or variegated marls variously acted on, and always accompanied by dikes of basalt. These hills continue about eight miles from Korah to the village of Ukri, where they gradually decline into a plain, throwing off numerous ridges or forks. About three miles distant, a solitary hill, with a flat but uneven top, called Baboa, rises out of the plain. To this hill I wish to draw particular attention; and the foregoing account of the basaltic range has been given as necessary to a proper understanding of it.

The first part of this plain is composed of thick beds of gravel, but

farther westward it consists of the nummulitic formation. Out of this soil rises the Baboa hill, composed of hard limestone, full of marine remains. One of the forks projecting from the basaltic range reaches to within half a mile of the hill, the ground near it being strewed with small fragments of igneous rock.

The cause of the elevation of this hill is, in my opinion, distinctly visible in the banks of a river which passes by its western base. They are from 20 to 30 feet in height, and are composed of white calcareous marl, covered by a thin bed of gravel. Immediately opposite the hill, these beds are cut through by a dike of very compact dark green basalt, forming, towards the river, a wall about eight feet high; its base being hid by a talus of gravel. In several places on each side of this dike, which is about 50 yards in breadth, independent masses of igneous rock break through the marl. They are principally of a blunt, conical form, capped with portions of the marl, and consist of spheroids of basalt, which desquamate in concentric layers, precisely resembling scales of iron. At a short distance up the river, or northward, this marl is covered by a stratified series, dipping at a high angle to the north, and consisting of a yellowish marl, with small imbedded fragments of lignite, covered by a bed of blue clay, containing also fragments of lignite and quantities of an olive-brown earth, in which small pieces of either amber or mineral resin are enclosed. Above this bed is a stratum of red sandstone; and the whole is covered, at its lower extremity, by a thick bed of gravel. These inclined beds reach the level of the water about 400 yards from the basaltic dike, beyond which the marl again appears in horizontal beds. Southward of the dike, the change from the broken part to the undisturbed horizontal strata, is much more abrupt, occurring within a very short distance. On the top of the bank adjoining the south end of the dike the stratified beds of blue clay, &c. are horizontal.

From the above description it appears that the only place in which the basalt is exposed is directly under the hill, no trace of it being discernible either above or below this spot; also, that the most compact and extensive mass of basalt is exactly under the highest part of the hill; and that detached masses of igneous rock present themselves, with large portions of the marl adhering to them. A series of stratified beds is also noticed rising from the north towards the hill, meeting the surface at its foot, and is again found in a horizontal position just south of the hill. All these facts surely prove, that the hill must have been elevated by an outburst of igneous matter, which was probably a branch from the basaltic hills to the eastward; one of its forks reaching within half a mile of the spot.

Quantities, of what I believe to be frothy or foam lava, being a

brownish-black substance, very vesicular or spongiform, extremely light, and somewhat similar to a very porous cinder, are found adhering to the marl, and in the rubble of the bank.

Large blocks of the shelly limestone, composing the summit of the hill, are scattered about its sides and base; and some of them, my guide informed me, fell during the earthquake of 1819; and the abrupt and steep sides are, no doubt, due to the action of water. Numerous fossils are found lying about, characteristic of the nummulitic limestone.

I have minutely described this hill, in the hopes of impressing others with the same belief as myself of the cause of its elevation.

Near the village of Nambye, in the Charwar range, a basaltic dike traverses beds of thinly laminated slate-clay and layers of limestone slate. In the immediate vicinity of the dike the strata dip in all directions, and form even, anticlinal lines. The basalt is very hard, compact, and of a dark blue colour, and presents irregular masses, without the slightest approach to a columnar structure.

Distinct Periods of Volcanic Eruption.—That the volcanic eruptions have occurred at many distinct periods is also evident, from the different formations with which the igneous rocks are associated, and from the variations in their characters. Thus, in the same section, the lower part frequently consists of large rolled or water-worn masses, whilst the upper portion is columnar; in other places the basalt alternates with a calcareous grit or coarse limestone, having a tabular structure, but always distinctly stratified, and very brittle, so as to present perpendicular banks. This limestone is generally associated with basalt, where the latter is raised into hills; and, from the fact of *angular* pieces of basalt or igneous matter being imbedded in it, would incline one to believe that, in such cases, it must be contemporaneous, though it often regularly alternates with it. In other places the basalt is interstratified with a pure crystalline limestone or travertin.

The principal mass of igneous rocks (see Map) lies towards the southern department of the province, and forms a group of hills called the Doura range; the intervening spaces and the ground at their southern base generally assuming a porphyritic structure. The northern parts of the range have, for the greater part, a flat, smooth outline; but in the interior of the group are many clusters of small, conical hills, arranged round a circular space, enclosing a kind of hollow. The sides of these cones are very steep, and invariably present innumerable horizontal lines, forming rings resembling narrow paths. The surface, being covered with basalt, in very small pieces, is totally devoid of vegetation, and has precisely the appearance of a newly-laid macadamised road. Their interior, however, has a much more solid construction, as is well seen

in numerous deep clefts and ravines with which the hills are in all directions intersected.

One of these ravines, near the village of Doonee, is 50 or 60 yards broad, and nearly 100 feet deep; and its perpendicular sides are composed of compact columnar basalt of a greenish grey colour; the columns being perfect polygons, and of a very large size. This rent must have been formed by some convulsion, as it reaches nearly to the summit of the hill; and the only water that could ever have flowed down it being that which falls on its sides and bed, and must be very little.

Alternations of Basalt with Strata of the Upper Secondary Formation.—Near Nurra, on the borders of the Runn, a hill called Jogé-ki-bit, basalt alternates with slate-clay, limestone slate, slaty limestone, and a laminated loam. The strata dip from 40° to 50° to the north, which, being at a higher angle than that at which the hill itself rises, it causes them to crop out; the surface being also broken into several distinct ridges. The igneous rock alternates three times. In one instance it underlies a stratum of hard slate-clay; in another it occurs between a coarse, soft sandstone, and slate-clay, and sandstone slate; and it also forms the conical summit of the hill, which is not more then ten feet in diameter. The basalt desquamates in flakes, but has a centre of compact rock. The same inclination of the beds is continued through the hill.

Alternations of the Calcareous Grit with Basalt.—At the village of Doonee, above mentioned, the banks of the river present a perfectly perpendicular wall, from 15 to 20 feet high, and are composed of the calcareous grit, or coarse limestone alternating with basalt, in the following order: first, grit; then, a horizontal bed of rounded pieces of basalt; and next, another stratum of the grit, 15 feet in thickness; the whole being covered by the basalt forming the hills.

Another good example of this alternation is near the village of Keroee, at the eastern limit of the formation. The banks of a river are here composed, in some places, of the basalt forming the Doura range; and in others entirely of the limestone grit, which in one place overlies the basalt, but forced up into anticlinal lines, as if the igneous rock had been protruded from below; the broken state of the strata showing that it was not originally deposited in this position. The bed of the river at this place is entirely composed of basaltic columns; their horizontal sections forming a regular pavement; and large masses of the columns, occupying from 200 to 300 square yards, and being about eight feet in height, remain, every here and there, similar to a field of corn partially reaped. The columns are very regular, generally four-sided, with smooth, even surfaces, and are composed of a hard, compact, dark blue basalt.

Another instance of the junction of the limestone grit with the basalt is near the village of Choolree, a little to the westward of Kaira. The basaltic range is completely divided by a narrow ravine, in which the two rocks appear in contact, the limestone being broken in all directions. One side of the ravine presents a perpendicular cliff, of nearly 80 feet in height, of irregular columnar basalt, overlying a bed of rounded masses of the same, though the opposite bank is composed of the limestone grit. Advancing through the Pass, the basalt terminates abruptly, and is succeeded by the limestone grit, which forms both sides of the ravine. Further on, the basalt again appears in the form of a dike; beyond which is the grit, once more succeeded by a dike of basalt, forming, at this extremity of the Pass, both banks. Where the dikes of basalt occur the limestone lies in immense masses, evidently broken off at the time of the projection of the upper bed of igneous rock; being itself of subsequent formation to the lower basaltic bed of rolled masses. This is very distinctly shown at one part of the Pass; and it should be mentioned that the bed of the ravine consists throughout of irregular or broken basalt.

The intervening spaces and the ground at the base of these hills are composed, for the most part, of a red clay, much resembling brick, a variety of it being amygdaloidal, of a darker colour, extremely hard and tough, and containing quantities of calcareous spar, chalcedony, rock crystal, &c.

In some places it forms low ranges of hills of a hard rock, of a dingy red colour, thickly interspersed with cylindrical kernels of zeolite, with a light green coating, some of them dividing into two parts. Other specimens contain numerous crystals of felspar; and, in many instances, all the mineral substances have disappeared, leaving a vesicular mass. Occasionally, thin beds or layers of calcareous spar, of a leek-green colour, are met with, also of rock crystal and chalcedony in all its varieties. The surface of the plains is covered with fragments of these minerals, derived from the disintegration of the amygdaloids, which are rapidly affected by exposure to air and water. Some of the sides of the hills are covered with heaps of rock crystal, as if cart-loads had been purposely thrown down.

Alternation of Basalt with Travertin.—A very good example of successive eruptions of basalt occurs near the small village of Wurrowsow, on the south-western flanks of the Charwar range. This point must at one period have been a lake, it being now a dead flat, about 4½ miles in diameter, and surrounded by low but steep hills, whose surfaces are covered with small fragments of basalt; its general level is about 20 feet above the ground to the east of it. The soil consists of alluvial matter and fine gravel, totally different from the sandy plain by which it is

bounded; but its most interesting feature is the basalt at the eastern outlet or break in the low surrounding hills. This mass of trap consists of perfectly polygonal columns about 25 feet in height, but broken into lengths, forming a series of regular steps, cut into a horse-shoe shape by a small stream, which discharges itself during the rainy season. The hills that flank it on each side are composed of a base of coarse sandstone capped by an earthy basalt, a dike of which, 8 or 9 inches wide, has, in one spot, penetrated the subjacent sandstone. The following is the section exposed in the horse-shoe part of the fall. (Pl. XIV. fig. 4.) The friable basalt forms the base of the fall. Above the columns the bed of the small stream consists of a loose, calcareous calc-tuff.

This section presents several interesting facts; as, from the alternation of basalt with the limestone or travertin, it is evident that a considerable time must have elapsed between the igneous eruptions. The variety in the texture of the limestone or travertin may be accounted for by supposing that the waters under which it was deposited were sometimes perturbed, or rendered muddy by a flood; but at other seasons clear, when a pure calcareous precipitate would take place. The basalt forming the columns is very hard, compact, of a dark blue colour, and smooth surface; and it may be traced to some small hills northward of the spot.

Near this place the surface has been affected in a manner worthy of observation. Every here and there, a small spot, varying in size from 3 to 20 yards in diameter, has been raised into a convex form; the pavement that covers it consisting of tabular plates of slaty sandstone, broken into small masses; and the fractured lines generally radiating, though in an irregular manner, from a centre. In some places the tops of these little globular elevations have been removed, leaving a regular circle of stones, whose bounding lines are disposed like the stones of an arch. In other instances they assume a more conical shape, resembling small hillocks, from the upper part of which the outer coating or tabular masses have generally fallen away. When they are of a larger character, the whole presents a heap of broken masses of rock.

Denodur Hill, and extinct Volcano.—Of the detached hills, the elevation of which I conceive to be due to volcanic influence, the principal is that called Denodur, and is situated near the shores of the Runn. It is the largest and highest hill in the country, and is evidently the remains of an extinct volcano, an irregular crater being still visible. In the north side is a large gap, reaching nearly to the foot of the hill, but partially blocked up by a lower ridge, or a kind of traverse. Its western flanks are composed of a series of ridges of laminated clay and loam, interspersed with flat, angular fragments of slaty sandstone and slate-

clay. The surface of some of these ridges is smooth, consisting either of thin slabs of slate-clay, or of thicker slabs of a very compact, crystalline, and slightly calcareous stone, the same as that which overlies the laminated series, and forms the walls on the Runn, &c. Near the base of the hill, and for more than two-thirds up its side, the construction alters, being composed partly of a loose sandstone, and partly of the calcareous grit, containing imbedded, angular fragments of basalt; the uppermost part is a perpendicular wall of basalt, which, apparently, continues all round the top. A stream of very compact basalt runs past its north-western flank, and in other places. Numerous small conical hills, composed of horizontal layers of limestone grit, or of basalt, are scattered over its sides, and its base is covered with a thick mould, formed of decayed vegetables, with earthy matter. Nowhere did I find any traces of recent disturbance, although the people of the neighbourhood, particularly the Jogees, or religious devotes, who inhabit a temple on its northern flank, asserted that fire issued from it during the earthquake of 1819. If it did, there would, of course, be some signs of it remaining; but I was unable to penetrate into the interior of the hill, owing to the dense Bauble Jungle, or crooked thorn tree with which it is covered.

Not far from this place, and adjoining the village of Nuckutrana, is a hill of some size, called Ungia-soorud, the elevation of which has also been effected by volcanic agency. The flanks and base are composed of a very loose, friable, calcareous sandstone and grit, apparently stratified, but inclined at all angles; and the remainder consists of very compact basalt. The hill is divided into two parts by a narrow, tortuous cleft, the sides of which are nearly perpendicular, and composed of irregularly triangular prisms of basalt. The cleft is not more than four feet wide at the bottom, though it is somewhat broader at the top; and as it passes completely through the hill, we must suppose the whole to be similarly composed.

All the other numerous isolated hills scattered over this part of the province, including that called the Nunnaw, next to Denodur, appear to be similarly constructed.

The hill called Lecka deserves particular notice. It forms one of a group of hills on the borders of the Runn, at the north-western extremity of the province, and is composed of two portions; one consisting of stratified beds of sandstone, and the other wholly of basalt, in irregular triangular columns. The beds of sandstone are horizontally disposed, and of various colours and textures; the lowest stratum being a coarse, brown, quartzose grit. The igneous rocks crop out in various places near this spot, forming a cluster of small hills between it and the Jooria range; the intervening spaces being broken in the most confused manner.

Recent Outbursts.—Having given as many examples of the elevatory

effects of volcanic action as my space will admit, I shall conclude my account of their phenomena with a description of some igneous outbursts of, apparently, a very recent epoch. The principal one occurs at the village of Wagé-ké-Pudda. The spot which has been acted on is a rather high table-land, composed of the nummulitic marl, and is flanked by low, irregular hills of ironstone and gravel, called by the natives Kara Rurraw. The first view of it is very striking. Conceive a space of about two square miles, blown out into a flat basin, the sides being broken into fissures, with craters, ravines, and hollows; and the interior, or bed of the basin, interspersed with hillocks and cones of every variety of colour, black, red, yellow, and white, and with patches of cinders, similar to the refuse of a furnace; the whole looking as fresh as if the igneous agents were still in operation.

The surface of the table-land immediately surrounding the blown-out space is covered with a burnt ironstone, divided into irregular cells, similar to Septaria; below which are steep banks, 40 to 50 feet high, consisting of comminuted particles of clay, sand, gravel, scoriæ, and small angular pieces of basalt; the whole being loose, and having a dry and brittle feel.

Within the centre are several small craters, or circular spaces, surrounded by walls of basalt. None of them are perfect circles, being broken through by watercourses; but one has about two-thirds of its circumference complete, the sides of which, about 40 feet high, are in the upper part quite perpendicular, and consist of very compact basalt, of a columnar structure; while the lower ten feet present a talus, composed of volcanic sand and scoriæ in very thin laminæ. Below the columnar basalt is a bed of a friable variety, three feet in thickness. In some parts the columns are capped with a thin band of ironstone. The interior of this crater is about 80 yards in diameter, and consists of volcanic sand, with imbedded angular fragments of basalt. The most perfect of these craters, or circular spaces, are generally hid from view, being approachable only by the narrow ravine forming the outlet of the watercourse which cuts through them. The basalt varies greatly in texture and general appearance; in some places it is columnar, exceedingly hard and compact, in others it contains imbedded crystals of felspar, and it occasionally presents the structure and texture of an amygdaloidal clay. Some varieties also consist of concentric layers of a kind of brittle, clayey substance, enclosing a nucleus of hard rock; the whole being imbedded in a mass of clay, which looks as if a number of small roots were entwined about it. All the varieties are frequently found in the same bank or hillock.

Several other small basins have been blown out in the surrounding table-land, forming inverted cones, about 15 or 20 feet in depth, and are

composed of the same materials as those just described. Many of them consist entirely of small, brittle particles, of a pale yellow colour, evidently sulphuric. The clay has, in various places, been burnt into a perfect brick; and the marls, or sandy clays, are frequently of a beautiful bright purple. Quantities of talc, or mica, lie scattered about, twisted and contorted into a variety of shapes; and some of the iron ore which covers the surface appears to have been partially fused, consisting of a spongy, vesicular mass. The whole has the appearance of having been for some time subjected to considerable heat, and then suddenly blown up. The cones and banks of loose volcanic scoriæ must be yearly washing away; and it is difficult to conceive that the walls of solid basalt, forming the sides of the craters, can belong to a similar period, having all the appearance and texture of very old basalt; but it is possible that a recent eruption may have taken place in the site of one of a more ancient date, thus presenting a mixture of old and recent volcanic products. If it is true, that basalt owes its columnar structure to its cooling slowly under a great pressure, it is impossible that these masses of columnar basalt and the loose cones of scoriæ can be contemporaneous.

In the nummulitic marl forming the banks of a river which flows past this patch of blown-up ground, is a stratum of earth containing small nodules or rounded masses, of a pale yellow colour, translucent and brittle, and which burn with a bright flame, giving out a strong aromatic odour. It is contained in a dry, olive-brown earth, so light as to float in water.

Numerous *Echinodermata*, and other fossils, are found on the table-land, and some of the fields are thickly strewed with casts of a Turbinella of a very large size, the external shell being always wanting. On breaking them, small fragments of igneous matter are found in their interior.

In the table-land just south of the outburst is a large fissure, about a quarter of a mile in length, 40 yards broad, and 40 or 50 feet deep. One extremity communicates with the river, and the other is rounded, or formed into a basin shape. The sides are perfectly perpendicular; and it is clearly an opening in the ground, there not being the slightest indication of anything of the kind, until directly at its brink. I was informed by a native of the village (the only present inhabitant), that smoke issued from the outburst about twenty-two years since; but little dependence can be placed on the statements of these people.

Another similar, but smaller, outburst occurs about three miles south of Mhurr, near the spot in which, in my account of the tertiary deposits, I mentioned that a large basaltic dike crosses the river. The space here blown out does not exceed 100 yards in diameter, and 15 feet

deep, consisting of similar cones of volcanic scoriæ, and comminuted particles, as above described; but there is no trace of any basalt nearer than the dike in the river.

From what I have now detailed, it appears that igneous action has affected all the formations of which the province is composed; and it will also appear, by the following details, that the Grand Runn, the most remarkable feature of the country, owes its peculiar characters to volcanic action.

The Grand Runn.

With a short account of this large and singular tract, I shall conclude the paper. It has been described by Captain Burnes, in a memoir in the library of the Royal Asiatic Society; and referred to, at considerable length, by Mr. Lyell, in his Principles of Geology.*

This tract, containing an area of upwards of 7,000 square miles, exclusive of the space occupied by the Bunnee, and the islands of Puchum, Khureer, &c., is perhaps, unparalleled in any known part of the globe, as it may be said to be placed on a level between land and water. It is dry during the greater part of the year, when its surface consists of a sandy flat, totally devoid of vegetation; but, perhaps, on account of its saline nature, always sufficiently moist to prevent its particles being drifted. During the prevalence of the south-west winds, however, so much water is blown up its eastern inlet by the Gulf of Cutch, and, at its western extremity, by the eastern branch of the Indus, as to cover its whole surface; augmented by the freshes, which, at the same time, come down the Loonee and Bunass rivers, and the numerous small streams which intersect the northern coast of Cutch. At those seasons the Runn has all the appearance of a sea, and is passable only on camels, and, in some seasons, with difficulty. It has been described as the dried-up bed of a sea; but it is not easy to account for its drying up, unless we suppose a general depression of the ocean. We must, therefore, look to other causes.

In several parts of the world, particularly in the Baltic, there are undeniable proofs of a gradual rising of the land; and, in time, parts of that sea might be converted into a tract similar to that of the Runn.† It does not become me to inquire whether this gradual elevation is due to a series of so minute elevatory movements as to be unnoticeable, except from the effects which subsequent measurement proves them to have produced, or from a gradual expansion by volcanic heat. But in Cutch we have evidence of movements within a very late date, and every reason to believe that similar ones have occurred at various

* 5th Edit. vol. ii. p. 183, *et seq.*

† See Mr. Lyell's Memoir on the proofs of gradual rising of the land in Sweden. Phil. Trans. 1835, p. 1, *et seq.*

periods. The earthquake of 1819 is known to have produced a remarkable change on the western extremity of the Runn, by throwing up a mound 50 miles in length, 16 in breadth, and 18 feet high; and by depressing an adjoining tract, so as to convert it, from a cultivated district, into a large salt lagoon. As the changes in level, thus effected, have, however, been detailed in other papers, I shall merely observe, that when I was at Luckput in January 1834, very little, if any, change had occurred since Captain Burnes's visit, in 1828, except that the Sindians had repaired all the bunds across the river, and thus, by preventing further supplies of fresh water, the lagoon had assumed much the same appearance as previous to the freshes of 1828.

I was also informed by a boatman, who constantly plied up and down from Ullah-Bund to the sea, that between Sindoo and Sindree (see Map) there is a bank, six miles broad, covered by only one foot of water; and, as there is no channel through it, the boatmen are obliged to get out and haul the boats across the bank, after which they follow the windings of the channel to Ullah-Bund. It would therefore appear that this portion could not have been so much sunk as that around Sindree, and between it and Luckput.

I was also assured that pieces of iron and ship-nails have been thrown up from fissures in the Runn; and Captain McMurdo* mentions a boat which had been buried under 15 feet of alluvium, having become exposed in a mud-bank, near the village of Wuwania, on the Kattywar side of the Runn, or where it joins the Gulf of Cutch.

The number of places still pointed out as Bunders, or quays, together with the large stones formerly used as anchors, one of which still lies on a small elevation on the Runn, not far from the Puchum Island, and the confident assertion of all the inhabitants on its coast, tend to confirm the opinion that the district must once have been covered by a navigable body of water.

Some parts of the shores have precisely the appearance of having been recently deserted by the sea. This is particularly the case near the village of Charee, which is separated from the Runn by a low range of hills. To the northward of this range is an inlet, about one mile and a half in breadth, and it looks precisely like a small creek or bay from which the tide has just ebbed. Its surface is composed of smooth, whitish clay, with numerous scattered gravel banks, the ends of which have been worn round, and the sides present perpendicular or overhanging banks. Several masses of crystalline sandstone also rise suddenly out of the bed; and some of them consist of immense fragments, which look as if they had been piled one on the other, and have a

* Extract from Captain McMurdo's MS. memoir on Kattywar, in Captain Burnes's Travels in Bokhara, vol. iii. p. 329, *note*.

strange effect from a short distance. Beyond the inlet is another range of hills of the same description, but it is more broken and confused than any other in the country. In some places, the upper stratum of hard rock has been thrown into a position like the roof of a house; in others, it precisely resembles a ruined fort with towers on a hill; but the greater part of the stratum is a confused assemblage of huge fragments of rock. Northward of this range, and separated from it by a narrow belt of the Runn, is a steep conical hill, called Keera, 600 or 700 feet in height, consisting partly of the same materials as the others, and partly of basalt; and it appears to have been formed in a similar manner to the hill called Ungur-soorud, before described, and others of that class. It is also more than probable that the peculiar, fractured appearance of all the ranges is due to the same cause acting at the same period.

Supposing the bed of the Runn to have been raised by a series of violent movements, such as must have upheaved the Keera, and its surface to have been broken, and covered with fragments of rock, its present level outline may be ascribed to subsequent operations. The Runn is bounded to the north, as already stated, by the Thurr or Little Desert, a district composed entirely of sand. The Loonee and Bunnas rivers also flow through a sandy soil, as do many other streams which enter from the Cutch side. Now, during the periodical floods, vast quantities of sandy alluvium must have been brought down by these rivers, deposited at their mouths, and washed thence and spread over the surface of the Runn by the sea-water annually blown up at its eastern and western extremities. This operation, repeated yearly, would fill up all inequalities, and produce in time a level surface. It is probable, however, that the present state of the district may also be, in some measure, owing to a gradual rising of its bed, as it is only to such operations that some of its shores, as those of the inlet above mentioned, can be ascribed.

There are also many facts to prove that this tract has been elevated at very different periods. The high hills bordering its southern shore are, as before stated, composed principally of the laminated series, and their surfaces are covered with Ammonites, Nautilites, Belemnites, and other fossils of that geological period; whereas, along its immediate line of shore, there are generally low ridges, composed of rocks full of marine remains of a totally different character, many of them belonging to existing species. Numerous small rocky islets, consisting of shells agglutinated into a solid mass, occur in various parts of the Runn, and are barely raised above its present level. They are probably merely the higher portions of large tracts, the lower parts of which are covered by sediment.

Natural Walls on the Runn, how formed.—Still more striking instances of the effects of upheavement, since the Runn assumed its present characters, are exhibited in the detached, elevated masses of rock which I have called the *Natural Walls* on the Runn.

They consist (see woodcuts*) of disconnected portions of rock rising abruptly from the surface of the Runn, and presenting a smooth, vertical wall, occasionally upwards of 30 feet in height, and in one instance upwards of two miles in length. Some of them resemble domed or vaulted buildings, the reversed side consisting of a talus of broken fragments of rock and soil. In one place these walls form a semicircle about 500 yards in diameter, both walls sloping outwards. That the walls have been uplifted into their present form is quite evident, first, from the stones being all on end, that is, with the grain in the direction of their present position, and peeling off in scales down the face of the wall; and secondly, from my having met with the same phenomena on a smaller scale, in other parts of the country, where the slabs of rock are at all angles, and even, as those before mentioned, turned over. It should be noticed, also, that the borders of the Runn, near these walls, are composed of friable beds of the laminated series, covered with thick tabular masses of hard sandstone, precisely similar to those forming the walls.

Had they been uplifted during the permanent prevalence of the waters, the sloping talus of earth and fragments of rock, with which they are all backed, must have been washed away. It should be stated, that these examples are situated on ground now almost recovered from a state of Runn, some parts having been sufficiently augmented by means of the sandy alluvium, washed down from the neighbouring hills to support vegetation; whereas the isolated rocks, several of which rise out of that part of the Runn, and are still subjected to inundation, have no detritus or talus, but present smooth walls of perpendicular rocks. I could never perceive any water-marks on them, nor any remains of marine testacea, which might occur, had the sea ever washed the present level of their foot. It is probable that their original base lines have become obliterated by the sediment which must have accumulated round them in course of time, and which forms the existing surface.

A very good example of a similar wall occurs in the centre of the province, near the village of Rampoora; it is a ridge of coarse sand-

* Plate XIV. fig. 5.—End view of a wall, about 15 feet high, and two miles long.
,, fig. 6.—Dome-shaped wall.
,, fig. 7.—One of the walls on the Runn, about 30 feet high, the stones divided into masses, but not broken.
,, fig. 8.—Side view of the same, showing the stones on end.
,, fig. 9.—Two walls on the Runn, forming a semicircle, but sloping outwards.
,, fig. 10.—Wall of sandstone near Rampoora.

stone about 300 yards in length, and from 10 to 15 feet in height, the stones being evidently placed edgeways, and in so regular a manner as to resemble precisely an artificial wall. It rises from a base of the same sandstone, and on one side it is nearly flat, but broken into masses, while on the other side are heaps of stone, broken and confused, and the interstices are filled with sand and small trees. At the extremity of the wall the stones slope up like the end of a roof. In the immediate vicinity of this wall is a small range of basaltic hills, striking, however, at right angles to the direction of the sandstone ridge.

Some of the rivers which flow towards the Runn from the Cutch side are lost in the sand at their mouths, though, at a short distance up the bed of the river, the stream runs freely. It would thus appear, that at these spots the bed of the Runn has been increased, by the sediment, probably brought down by the stream ; but so loose is the soil, that the water soaks into it and even flows under it, instead of wearing channels. This phenomenon is observable in the sandy beds of many of the rivers in the province. The stream may be noticed running with some rapidity, and of a sudden to cease, the bottom of the river presenting a smooth sandy surface ; but a mile lower down the water again issues and continues its course ; the intervening parts being sometimes quite hard and dry ; in others forming very dangerous quicksands.

The natives have various traditions that the drying up of this sea was sudden, and that boats were tossed on the land and wrecked ; they pretend also to assign a date to this event, but their accounts differ so materially and are so vague that not the slightest reliance can be placed upon them, except to the general fact.

It is evident that the Runn could not have been drained by the bursting of its boundaries, at least since it was deep enough to be navigable ; because its present surface, notwithstanding the sediment which yearly accumulates on it, is even now so little raised above the sea's level as to be flooded by the mere effects of the wind ; but the most probable supposition is, not that it was ever a detached inland sea or lake, but that it communicated with the ocean by its present outlets, and that its bed has been raised, partly perhaps by a gradual movement, and partly by violent upheavements during earthquakes. Even such marked changes of level as the raising of Ullah-Bund, and the sinking of the ground near the large town of Luckput, would have passed unrecorded but for the accidental circumstance of the district having been visited by a British officer. Other portions of this vast area, the greater part of which is never traversed by man, may have been similarly affected at that time, and yet the changes remain unknown.

Successive Marine and Fresh-water Beds.—The submerged tract near

Luckput, or Lake of Sindree, may, I think, illustrate the manner in which successive marine and fresh-water deposits may be produced. This tract was at one period a richly cultivated district, periodically flooded by a branch of a great river, and produced large quantities of rice. In this state numerous land testacea no doubt occupied it, and were mixed with the remains of fluviatile species brought down by the floods. The bones of animals used in agriculture, and those of various domestic species, also the remains of broken pottery, perhaps coins, and other proofs of civilised life, might likewise have been imbedded. Suddenly, owing to the damming up of the river by the Sindians, the supply of fresh water ceased, and the tract was no longer cultivated or inhabited. Some time after this an earthquake occurred, uplifting one part and depressing below the level of the ocean another, which was immediately converted into a salt lake. A perfectly new description of deposit and organic remains must then have been accumulated, consisting wholly of marine animals, principally such as inhabit shallows and tide-ways. Again, owing to the sudden melting of the snow on far distant mountains (the Himalayahs), the waters of the river came down with such force as to burst all the bunds built across it, as well as that thrown up by the earthquake, and covered the tract with fresh water, or perhaps with fresh at its upper or northern extremity, and brackish at its southern near the sea. Supposing this state of things to have remained for some time, the river continuing to pour its water into this lagoon, another change would take place in the description of the sedimentary deposit. Once more the bunds were erected across the river, the supply of fresh water ceased, and, as that on the lagoon evaporated, the sea again flowed in and converted it into a salt lake, which is its present state. All the above changes are known to have occurred ; and it is easy to suppose that if the shallow part at Sindoo were slightly raised above its present level, thus shutting out the sea, the part around the Fort of Sindree would be converted once more into dry land. If, therefore, at any future period, the river should again cut a channel, the banks might present various, regular beds alternately enclosing marine and fresh-water exuviæ, the latter being also associated with land productions.

The ruins of one of the towers of the Fort of Sindree remained, when I visited Luckput in 1834, and in all probability now stand as a monument of the changes which are daily taking place on the earth's surface.

Conclusion.—In concluding this paper, I have only to observe, that I have throughout endeavoured to describe facts as they appeared to me at the time I examined them, without regard to any particular theory ; and if I have failed in making my descriptions intelligible, I have only to plead the difficulty of having had a great deal to describe in a limited

space. As the country to which this memoir relates is, however, unfortunately from its geographical position, beyond the reach of general observers, I am induced to hope, that this sketch, however imperfect, may be found to possess some interest.

For the arranged list of fossil shells, given in the Appendix, as well as for all my information on that subject, I am entirely indebted to Mr. James DeCarl Sowerby, who had my specimens (now in the cabinets of the Geological Society) for some time in his possession for examination.

The sketches are copied from drawings taken by myself on the spot, for the express purpose of geological illustration, and are unexaggerated views of what they are intended to represent.

December 31*st*, 1836.

APPENDIX.

SYSTEMATIC LIST OF ORGANIC REMAINS; THE PLANTS DETERMINED BY MR. JOHN MORRIS, AND THE REMAINDER BY MR. JAMES DE CARL SOWERBY, A.L.S.

The fossils considered as belonging to previously described species are distinguished by a reference to the work in which they were first noticed; the new species are described in the explanation of the plates at the end of the part.

Class, Genus, and Species.	Plate.	Formation.	Locality.	Remarks by Captain Grant.
PLANTÆ.				
Ptilophyllum acutifolium	XV. 1 a—3.	Sandstone, Clay with Coal.	South of the Charwar range.	
——— *Cutchense*	„ 4.			
Lycopodites affinis	„ 5.			
Fucoides (*Codites?*) *dichotomus*	„ 7.			
Stems of Equisetites or a Monocotyledonous Plant	„ 1 b, 6.			
POLYPARIA.				
Lycophris Ephippium (p. 415 *Orbitolites.*)	XVIII. 15, 15 a, b.	Nummulitic group.	Baboa Hill and Wagé-ké-pudda.	Very abundant.
——— *dispansus*	„ 16, 16 a, b.	Ibid.		
RADIARIA.				
Crinoidal stems	XVII. 14-16.	Upper Secondary.	Charee.	Found on hills near Charee with Ammonites and other fossils.
Echinus dubius	XVIII. 18.	Nummulitic group.	Baboa Hill, Wagé-ké-pudda.	
Galerites pulvinatus	„ 19.	Ibid.	Baboa Hill.	
Clypeaster affinis ? Goldfuss, XLII. 6.	„ 20, 20 a.	Ibid.	Ibid. and near Joongrea.	
——— *varians*	„ 21, 21 a.	Ibid.	Ibid. and Wagé-ké-pudda.	
——— *depressus*	„ 26, 26 a.	Tertiary.	Soomrow.	Found in great numbers, and similar in colour and form, to recent specimens, but flatter.
——— *oblongus* Lamk.	„ 25, 25 a.	Ibid.	Between Joongrea and Kotra.	

Class, Genus, and Species.	Plate.	Formation.	Locality.	Remarks by Captain Grant.
Spatangus obliquatus S. Buckl.? Goldf. XLVII. 6.	XVIII. 22, 22 a, b.	Nummulitic group.	Baboa Hill.	Very numerous.
—— *acuminatus?* Goldf., XLIV. 2.	,, 23, 23 a—c.	Ibid.	Ibid.	
—— *elongatus*	,, 24.	Ibid.	Ibid.	
ANNULATA.				
Serpula? recta	XIX. 1.	Tertiary.	Near Kotra.	Bodies of similar form occur in vast quantities on isolated banks in the river near Kotra.
Siliquaria Grantii	,, 2.	Ibid.	Borders of the Runn.	
CIRRIPEDA.				
Balanus sublævis	,, 3.	Ibid.	Soomrow.	
CONCHIFERA.				
Pholadomya? inornata	XV. 8.	Upper Secondary.	Near Charee.	Found on some hills bordering the Runn, which have been much disturbed by volcanic action.
—— *granosa*	,, 9.	Ibid.	Ibid.	
—— *angulata*	,, 10.	Ibid.	Ibid.	
Amphidesma? ovale	,, 11.	Ibid.	Ibid.	
—— *? hians*	,, 12.	Ibid.	Ibid.	
Corbula lyrata	,, 13.	Ibid.	Ibid.	
—— *trigonalis*	XIX. 4.	Tertiary.	Borders of the Runn.	
—— *rugosa*	,, 5.	Ibid.	Ibid.	
Tellina exarata	,, 6.	Ibid.	Soomrow.	
Astarte unilateralis	XV. 14.	Upper Secondary.	Charee.	
—— *pisiformis*	,, 15.	Ibid.	Ibid.	
Venus granosa	XIX. 7.	Tertiary.	Soomrow.	
—— *cancellata*	,, 7.*	Ibid.	Ibid., Kotra.	
—— *nonscripta*	,, 8.	Ibid.	Soomrow.	
Pullastra? virgata	,, 9.	Ibid.	Ibid.	
Cardita intermedia? Brocchi, XII. 15.	,, 10.	Ibid.	Ibid.	
Trigonia costata, var. M. C., LXXXV.	XV. 16.	Upper Secondary.	Charee.	Found in the same hills with the Pholadomyæ.
—— *pullus*	,, 17.	Upper Secondary.	Charee.	Found in the same bed as *Trigonia costata*.
Cardium intermedium	XVIII. 1.	Nummulitic group.	Baboa Hill.	
—— *ambiguum*	,, 2.	Ibid.	Ibid.	
—— *triforme*	XIX. 11.	Tertiary.	Soomrow.	

Cucullæa virgata	XVI. 1, 2.	Upper Secondary.	Hubbye Hills.	A pass in the hills between Hubbye and Joorun is paved with these shells imbedded in a hard rock.
Arca hybrida	XVIII. 3.	Nummulitic group.	Baboa Hill.	
—— *radiata*	XIX. 12.	Tertiary.	Soomrow.	
—— *tortuosa ?* Linn.	,, 13.	Ibid.	Ibid.	
Pectunculus pecten	XVIII. 4.	Nummulitic group.	Baboa Hill.	
Nucula tenuistrata.............	XVI. 3.	Upper Secondary.	Hubbye Hills.	In the same masses with *Cuc. virg.*
—— *? cuneiformis*............	,, 4.	Ibid.	Charee.	These shells form stony banks which project slightly above the bed of the Runn; also solid rocks in the Hubbye Pass.
—— *Baboensis*	XVIII. 5.	Nummulitic group.	Baboa Hill.	
Pecten partitus	XVI. 5, 5 a.	Upper Secondary.	Hubbye Hills.	
—— *lævicostatus*	XVIII. 6.	Nummulitic group.		
—— *Soomrowensis*	XIX. 14.	Tertiary.	Soomrow.	
—— *articulatus*..............	,, 15.	Ibid.	Banks of the Runn.	
Plicatula pectinoides	XVI. 6.	Upper Secondary.	Near Charee.	
—— —— M. C., CCCCIX.	,, 9 a.	Ibid.	Katrore Hill.	
Exogyra conica .... M. C., XXVI., DCV.	,, 7.	Ibid.	Ibid.	
Gryphæa globosa ?............. M. C., CCCXCII.	XIX. 16.	Tertiary.	Kotra.	
Ostrea Marshii .... M. C., XLVIII.	XVI. 9.	Upper Secondary.	Katrore Hill, Charwar range.	Found in a bank in the hill.
—— *carinata ?* .... M. C., CCCLXV.	,, 8.	Nummulitic group.	Charee.	
—— *callifera ?* .... Lamk.	XVIII. 7.	Ibid.	Wagé-ké-pudda.	Isolated banks in the broad river bed near Kotra are completely covered with these oysters.
—— *orbicularis*.............	,, 8.	Ibid.	Luckput.	Masses, 15 to 20 feet thick, composed of this shell, are scattered in the bed of the river.
—— *angulata*...............	XIX. 17.	Tertiary.	Kotra.	
—— *Flabellulum* .... M. C., CCLIII.	,, 18.	Ibid.	Cheeosir.	The banks of a river near Cheeosir are composed of a grit full of these fossils, and of a Cardium. They are generally distributed through the tertiary district.
—— *tubifera*	,, 19.	Ibid.		
—— *lingua*	,, 20.	Ibid.	Near Joonagrea and Kotra.	
Terebratula intermedia, var. .... M. C., XV. 8.	XVI. 10.	Upper Secondary.	Charee.	
—— *biplicata, var.*......... M. C., XC. & CCCCXXXVII.	,, 11.	Ibid.	Jooria Hill.	

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Class, Genus, and Species.	Plate.	Formation.	Locality.	Remarks.
Terebratula sella, var. M. C., CCCCXXXVII. 1.	XVI. 12.	Upper Secondary.	Pass of the Hubbye Hills.	
——— *concinna?* M. C., LXXXIII. 6.	„ 13.	Ibid.	Jooria Hill.	
——— *nobilis*	„ 14.	Ibid.	Near Charee.	Very numerous.
——— *dimidiata?* M. C., CCLXXVII. 5.	„ 15.	Ibid.	Near Jooria Hill.	One specimen was found in gold-coloured oolite, in the highest part of the Jooria Hill on the borders of the Runn.
——— *mojor*	„ 16.	Ibid.	Charee.	
MOLLUSCA.				
Bulla lignaria, Linn.	XX. 1.	Tertiary.	Soomrow.	
Neretina grandis	XVIII. 9.	Nummulitic group.	Wagé-ké-pudda.	
Natica obscura	XX. 2.	Tertiary.	Soomrow.	From the lower part of the hills. The shells found in this position differ from those in the highest part of the same hills, and appear to have been deposited in the shores of the Runn since those hills were raised.
——— *callosa*	„ 3.	Ibid.	Ibid.	
Globulus obtusus	XVIII. 10.	Nummulitic group.	Baboa Hill.	
———*? anguliferus*	XX. 4.	Tertiary.	Borders of the Runn.	
Solarium affine	„ 5.	Ibid.	Soomrow.	Very numerous.
Trochus cognatus	„ 6.	Ibid.	Ibid.	
Turritella angulata	„ 7.	Ibid.	Ibid.	Very numerous.
——— *assimilis*	„ 8.	Ibid.	Ibid.	
Terebra reticulata	„ 9.	Ibid.	Ibid.	
Cerithium rude	„ 10.	Ibid.	Ibid.	Numerous, but imperfect.
——— *corrugatum*	„ 11.	Ibid.	Ibid.	
Fussus? granosus	„ 12.	Ibid.	Ibid.	
——— *læviusculus*	„ 13.	Ibid.	Ibid.	
——— *nodulosus*	„ 14.	Ibid.	Ibid.	
———, or *Murex hexagonus*	„ 15.	Ibid.	Ibid.	
Ranella bufo	„ 16.	Ibid.	Ibid.	
Rostellaria rimosa M.C.,X.C.I., not Lamk.	„ 17.	Ibid.	Ibid.	
——— *rectirostris*, Lamk.	„ 18.	Ibid.	Ibid.	
Strombus deperditus	„ 19.	Ibid.	Ibid.	
——— *nodosus*	„ 20.	Ibid.	Ibid.	
Cassis sculpta	„ 21.	Ibid.	Ibid.	

Buccinum pumilum	XVII. 1, 1 a.	Upper Secondary?	Mhurr.	Found in a mass of white marl.
Turbinellus bulbiformis	XVIII. 11.	Nummulitic group.	Wagé-ké-pudda.	Found in vast quantities, and sometimes very large.
——— *affinis*	XX. 22.	Tertiary.	Soomrow.	
Mitra scrobiculata? Brocchi	,, 23.	Ibid.	Ibid.	
——*fusiformis*	,, 24.	Ibid.	Ibid.	
Voluta jugosa	XX. 25.	Tertiary.	Soomrow.	Among the most numerous fossils found at Soomrow.
——— *dentata*	,, 26.	Ibid.	Ibid.	
Cypræa depressa	XVIII. 12.	Nummulitic group.	Baboa Hill.	
——— *humerosa*	XX. 27.	Tertiary.	Soomrow.	
——— *prunum*	,, 28.	Ibid.	Eycrau.	
——— *digona*	,, 29.	Ibid.	Soomrow.	
——— *nasuta*	,, 30.	Ibid.	Ibid.	
Seraphs	..	Nummulitic group.	Baboa Hill.	An imperfect cast.
Terebellum obtusum	,, 31.	Tertiary.	Soomrow.	
Oliva pupa	,, 32.	Ibid.	Ibid.	Found in great quantities.
Conus brevis	,, 33.	Ibid.	Ibid.	Very numerous.
—— *militaris*	,, 34.	Ibid.	Ibid.	
—— *catenulatus*	,, 35.	Ibid.	Ibid.	
—— *marginatus*	,, 36.	Ibid.	Ibid.	
Belemnites canaliculatus? *Schlotheim*	XVII. 2.	Upper Secondary.	Charee.	
————	,, 3.	Ibid.	Ibid.	
Nautilus hexagonus? M. C., DXXIX.	,, 4.	Ibid.	Ibid.	
Ammonites Herveyii, var. M. C., CXCV.	,, 5.	Ibid.	Ibid.	Ammonites are exceedingly numerous throughout the district coloured in the map, as Upper Secondary, and are generally loose on the surface. In the text (p. 412) eight species are mentioned as new, but on further examination two of them have been ascertained to be only varieties.
——— *elephantinus*	,, 6.	Ibid.	Ibid.	
——— *formosus*	,, 7.	Ibid.	Ibid.	
——— *lamellosus*	,, 8.	Ibid.	Ibid.	
——— *Opis*	,, 9.	Ibid.	Ibid.	
——— *arthriticus*	,, 10.	Ibid.	Ibid.	
——— *ignobilis*	,, 11.	Ibid.	Ibid.	
——— *corrugatus?* M. C., CCCCLI.	,, 12.	Ibid.	Ibid.	
——— *armiger*	,, 13.	Ibid.	Ibid.	
Nummularia acuta	XVIII. 13, 13 a.	Nummulitic group.	Luckput.	Nummularia are so abundant as almost to compose a large tract on the north-west frontier of the province.
——— *obtusa*	,, 14, 14 a.	Ibid.	Wagé-ké-pudda.	
Fasciolites (Parkinson), elliptica	,, 17, 17 a.	Ibid.	Ibid. Baboa Hill.	

EXPLANATION OF THE MAP AND PLATES.

Map.

Map.—This map, to illustrate Captain Grant's Memoir on Cutch, drawn to a scale of about 11 miles to an inch, is taken principally from one by Captain A. Barnes; corrected from other sources, and from my own observations. The geological divisions marked on it do not profess to follow the exact boundaries of each formation, but merely to give in a general view as correct an idea of them as my examination of the country enabled me to do. The blank part, near the upper right-hand corner of the map, shows the portion of the Runn flooded by the Loonee river during the monsoons. The section is intended to give merely an idea of the different ranges of hills, as well as to show the manner in which the surface of the province is occupied by each formation.

PLATES XV. to XX.*

Plate XV.

Plants from the Sandstone and Clay, with beds of coal; and shells from the Upper Secondary Formation; pp. 406, 410.

Plants described by Mr. J. Morris.†

Ptilophyllum.

Stem —? Fronds pinnate; pinnæ closely approximated, linear, lanceolate, more or less elongate, imbricate at the base, attached obliquely; base semicircular or rounded; veins equal, slender, parallel.

We have ventured to form these fossils into a distinct genus, conceiving that the circumstances of the oblique insertion of the pinnæ and their overlapping each other at the base, are characters too important to admit of their being united to the genus *Zamites*, to which somewhat similar fossils have hitherto been referred; the *Z. pectinata* of the Fossil Flora belongs to this genus, and a careful revision of the fossil *Cycadeæ* may probably discover other species having this mode of attachment; from the structure of the frond they may, however, be considered to belong to *Cycadeæ*, and to differ from *Zamites* in the oblique insertion of the pinnæ at the base, and from *Coniferæ* by the absence of a primary vein in the pinnæ.

Ptilophyllum acutifolium, t. 21. f. 1 *a*, 2, 3.

Frond pinnate; pinnæ narrow, linear-elongate, acute at the apex.

This species differs from the *Z. pectinata* of the Fossil Flora, in its pinnæ being narrower, longer, and more acute; and more nearly resembles the *Polypodites pecteniformis* of Sternberg.

P. Cutchense, t. 21, f. 4.

Frond pinnate; pinnæ short, scarcely overlapping at the base, apex obtuse.

This specimen has been also referred to the genus from its pinnæ (although wider apart than in the other species) having apparently a rounded base; but the

* The numbers of the Plates *in orig.* are XXI. to XXVI.—Ed.

† The plants are stated in p. 408 to consist of ferns and reeds, but when the Memoir was passed through the press the specimens had not been examined by Mr. Morris.

absence of all trace of venation in this fossil must render its correct determination very doubtful. It resembles in form the *Z. Bucklandii* of Sternberg, parts 5 and 6, t. 23, f. 2, or even *Z. taxina* of the Fossil Flora; and it might also be compared to some pinnatifid Polypodiums, as *P. plumula* and *P. taxifolium.*

It is much to be regretted that more numerous and better-preserved portions of these specimens have not been obtained, so as to compare them more rigidly with the already known forms of fossil vegetation; for it is remarkable the analogy that some of them present to the Stonesfield slate plants.

Lycopodites affinis, t. 21, f. 5.

Stem ——? branches linear-elongate, leaves distichous, alternate, ovate-lanceolate, acuminate, adnate at the base.

This specimen has been referred to Lycopodites from its resemblance to the barren portions of *Lycopodium Jussieni* and *L. volubile.*

————, t. 21, f. 1 *b*, f. 6.

These specimens were probably portions of stems belonging either to *Equisetites* or some monocotyledonous plant.

Fucoides dichotomus, t. 21, f. 7.

Frond compressed? dichotomous; branches unequal, patulate, apex obtusely rounded.

The Shells in this and the following Plates are figured and described by Mr. James De Carl Sowerby.

Fig. 8. *Pholadomya? inornata.* Transversely elongate, ovate, gibbose, concentrically corrugated; beaks very near the anterior extremity; longitudinal ribs very obscure, rounded. Width 1½ inch, length nearly 11 lines.

Loc. near Charee.

Fig. 9. *Pholadomya granosa.* Ovate, subtriangular, gibbose, ornamented with four or five rows of transversely-elongated and but slightly-elevated tubercles; the anterior side nearly straight-flattened, the posterior produced; beaks very prominent. Length 2 inches, width the same.

Loc. near Charee.

Fig. 10. *Pholadomya angulata.* Subtrigonal, gibbose, ornamented with four or five sharp ribs, which are most prominent near the edge; anterior side straight, nearly flat. Length and width equal; in some specimens 2 inches.

Ph. angulata approaches *Ph. Murchisoni* var. of Phillips. (Geol. of Yorks., Pl. VII. f. 9.)

Loc. near Charee.

Fig. 11. *Amphidesma? ovale.* Transversely elongate, ovate, convex, slightly wrinkled, anterior side small, truncated, distinguished from the rest of the shell by a gentle depression; posterior extremity rounded, rather pointed. Length 11 lines, width 1 inch 4 lines.

Loc. near Charee.

There is no proof whatever that either this or the following belong to the genus *Amphidesma;* they are, however, very nearly related to *A. donaciforme* and *A. securiforme* of Phillips.

Fig. 12 *Amphidesma? hians.* Transversely elongated, convex, slightly wrinkled; sides gaping; the anterior small, separated from the rest of the shell by an obscure depression; the posterior rounded, a little flattened. Length 1 inch,

width more than $1\frac{3}{4}$ inch: the specimen being broken, we have not the measure complete.

Loc. near Charee.

Fig. 13. *Corbula lyrata.* Rounded, triangular, convex, transversely ribbed; ribs about 15, prominent, rounded; posterior side of the larger valve formed into a distinct lobe, convex, nearly smooth—the beak of the same valve much incurved, the margin toothed. Length and breadth nearly equal, sometimes exceeding half an inch.

Occurs grouped in dense masses with *Trigonia Pullus*, a smooth *Uncula*, &c.

Loc. near Charee.

Fig. 14. *Astarte unilateralis.* Transversely obovate, anteriorly truncated, convex, rather flattened, and marked with 8 or 9 concentric rugæ near the beaks. Anterior side at right angles with the hinge line; lunette concave, ovate, pointed. Width greater than the length, but variable in proportion, generally about $1\frac{1}{2}$ inch. We have given a view showing the lunette on the right hand.

Loc. near Charee.

Fig. 15. *Astarte pisiformis.* Nearly globose, with pointed beaks; marked with 8 or 9 sharp transverse ridges; edge toothed. Length 3 lines.

Loc. near Charee.

Fig. 16. *Trigonia costata*, var. This shell varies slightly both in form and markings—generally the form is between that of *T. costata*, Parkinson or M. C. t. 85; and *T. elongata* of M. C. t. 431; which Lamarck, apparently with justice, considers to be but one species.

Loc. near Charee.

Fig. 17. *Trigonia Pullus* (M. C. t. 508, f. 2, 3)? The markings on the posterior side are not so regular as in the English specimens, but there is no other difference.

Loc. near Charee.

Plate XVI.

(Fossils from the Upper Secondary Formation, Cutch.)

Figs. 1, 2. *Cucullæa virgata.* Transversely elongato-quadrate, with projecting incurved beaks, very convex, marked with many longitudinal irregular, sharp ribs; posterior margin obliquely truncated. Length $1\frac{1}{2}$ inch, width $2\frac{1}{4}$ inches.

Loc. between Hubbye and Joorun.

Fig. 3. *Nucula tenuistrata.* Obliquely oval, finely striated concentrically; beaks close to the anterior extremity. Length 4 lines, width 5 lines.

Specimens very imperfect, along with *Cucullæa virgata* (fig. 2).

Loc. between Hubbye and Joorun.

Fig. 4. *Nucula? cuneiformis.* Transversely elongate-elliptical, gibbose, smooth; beaks close to the anterior extremity, small, incurved. Length 6 lines, width 10 lines.

Loc. near Charee.

Fig. 5, 5*a*. *Pecten partitus.* Broad, short-elliptical, depressed, marked with two concave radii, which divide the surface into three parts, both externally and internally, the lateral parts being flattened; concentrically and minutely waved, waves alternately larger and smaller; ears small, nearly equal. Fig. 5 *a* is a magnified portion of the surface. Length 6 lines, width 5 lines.

Loc. Hubbye Hills.

Fig. 6. *Plicatula pectinoides* (M. C. t. 409). If this differ at all from the British species, it is in having rather more the habit of an *Ostrea,* which is apparent in the expansion of the edge.

Loc. near Charee.

Fig. 7. *Exogyra conica* (M. C. t. 26 and 605). The few specimens most detached from the matrix appear not to be quite so deep as those figured in the Mineral Conchology.

Loc. Katrore Hills.

Fig. 8. *Ostrea carinata* (Lam. Hist. Nat. vol. vi. 216, M. C. 365)? The specimens being generally much concealed in the stone, or broken, the determination of the species is not possible; the most perfect individuals resemble the young state of *O. carinata,* but that species is so near in some slates to *O. gregaria* (M. C. t. 111), and *O. solitaria* (M. C. t. 468); that fragments cannot be distinguished.

Loc. near Charee.

Fig. 9. *Ostrea Marshii* (M. C. t. 48). The *O. Marshii* varies so much in different localities, that we find no difficulty in referring this shell to that species, although the plaits are more numerous than usual.

This specimen is accompanied with an imperfect *Plicatula* (fig. 9 *a*).

Loc. Katrore Hill.

Fig. 10. *Terebratula intermedia* (M. C. t. 15, f. 8) *var.* A small specimen, and rather more deeply plaited than most of the European varieties of the species.

Loc. near Charee.

Fig. 11. *Terebratula biplicata* (M. C. t. 90 and 437, f. 2, 3) *var.* A variety of this variable species found in the red chalk at Hunstanton, is precisely similar in form to our specimen, except that it wants the angle on each side of the beak which is here obscurely visible.

Loc. Jooria Hill.

Fig. 12. *Terebratula Sella* (M. C. t. 437, f. 1) *var.* A rather longer shell than the British fossil, and deficient in the central plait, which most generally occurs in full-grown individuals of that species.

Loc. Pass of the Hubbye Hills.

Fig. 13. *Terebratula concinna* (M. C. t. 83, f. 6)? A larger shell than the one figured in M. C. and not so neat, but hardly possessing any character sufficiently strong to mark it as a species; there are, however, rather fewer plaits.

Loc. Jooria Hill.

Fig. 14. *Terebratula nobilis.* Tetrahedral, rounded, sharply plaited; plaits about 16, extending to the beaks, 4 or 6 of them much elevated along the middle of the disk; beaks small, adpressed; sides concave near the beaks.

A large handsome species; when young the general form is depressed, but the middle is even then much elevated. Length and width, each $1\frac{3}{4}$ inch, depth of the valves united, sometimes more than 2 inches.

Loc. near Charee.

Fig. 15. *Terebratula dimidiata* (M. C. t. 277, f. 5)? Whether this be *T. dimidiata* or *T. inconstans* (M. C. t. 277, f. 4), is a question the specimens are not perfect enough to settle. The flattened form of the specimen figured agrees with that of *T. dimidiata,* but the beaks of our specimens appear too much incurved (perhaps from pressure), and so to approach *T. inconstans.*

Loc. Jooria Hill, and near Charee.

Fig. 16. *Terebratula major.* Transversely obovate, gibbose, plaited; plaits angular, extending to the beaks, about 30, half of them on one side of the front slightly raised; beak of the larger valve prominent, slightly incurved. A larger species than the last, of the same family, well distinguished by its width and even surface. Length, 1¾ inch, width 2¼ inches, depth of the valves united 1½ inch.

Loc. near Charee.

Plate XVII.

(Fossils from the Upper Secondary Formation, Cutch.)

Fig. 1, 1 *a*. *Buccinum pumilum.* Ovate, pointed, transversely striated; spire small; whorls 4, smooth in the middle, slightly convex; aperture ovate, pointed at both extremities. Fig. 1 *a* is magnified twice. Height 3 lines, diameter 2 lines.

Loc. Mhurr.

Fig. 2. *Belemnites canaliculatus*, Schloth. (Zieten, t. xxi. f. 3)? The fragments we have of this Belemnite agree well with Zieten's figure of *B. canaliculatus*, which is very probably not distinct from *B. sulcatus* of Miller (Geol. Trans. 2nd Series, vol. ii. part 2, p. 59, Pl. VIII. f. 3).

Loc. near Charee.

Fig. 3. *Belemnites* ——— ? A nearly cylindrical fragment without a sulcus. Very like *B. elongatus* of Miller.

Loc. near Charee.

Fig. 4. *Nautilus hexagonus* (M. C. t. 529)? Flatted spheroidal, with a very small umbilicus; front approaching to flat; sides rather conical; septa 15 in a whorl; aperture wider than long; siphuncle unknown. Diameter 3¼ inches, thickness 2¼ inches, length of the aperture 1½ inch.

This differs from *N. hexagonus* in having a smaller umbilicus and in being more rounded. It wants the line that occurs in the middle of the front of *N. lineatus,* which it nearly resembles. The figure is reduced to half the natural size.

Loc. near Charee.

Fig. 5. *Ammonites Herveyi* (M. C. t. 195, Zieten, 19, t. xiv. p 3) *var.*

This differs from the English specimens only in having a wider umbilicus. It agrees well with Zieten's figure, which differs a little from the English specimens, to which *A. macrocephalus,* figured by the same author at Tab. 5, f. 1 and 4, approaches nearer. The figure is reduced one-half.

Loc. near Charee.

Fig. 6. *Ammonites elephantinus.* Approaching to globose, with a very wide umbilicus exposing the inner whorls; whorls obtusely angular at their sides, crossed by very prominent rounded costæ, which divide into two as they pass over the front; aperture transversely elongated, gently arched. Diameter 4 inches, thickness 2½ inches, length of aperture above an inch. The figure is reduced to half the natural size.

Loc. near Charee.

Fig. 7. *Ammonites formosus.* Discoid, with a rounded edge, umbilicate, radiated; umbilicus narrow, acutely conical; radii numerous, slightly elevated, obscure near the umbilicus, often forked near their commencement, passing in a direct course over the front; aperture sagittate, with truncated angles. Diameter 5

inches, thickness 2¼ inches, length of aperture 1½ inch. This is reduced in the figure to half its size.

Loc. near Charee.

Fig. 8. *Ammonites lamellosus.* Discoid, thick, with a rounded margin, umbilicate, radiated; umbilicus narrow, exposing a small portion of each inner whorl, smooth; radii numerous, elevated into obtuse lamellæ, commencing with a curve upon the edge of the umbilicus, often forked upon the middle of the sides, bent forward as they pass over the margin. Diameter 4 inches, thickness 1¾ inch. The figure is reduced one-half.

Loc. near Charee.

Fig. 9. *Ammonites Opis* . . . Discoid, compressed, with an obtuse edge, radiated; inner whorls one-third exposed; whorls slightly convex on their sides, their inner edge rounded; radii commencing with a curve at the inner edge of the whorls, numerous, prominent, rounded, often forked near the middle, slightly bent forward as they pass over the front; aperture elliptical. Diameter 4¼ inches, thickness 1¼ inch, length of aperture 1¼ inch. This figure is also reduced one-half.

Loc. near Charee.

Fig. 10. *Ammonites arthriticus.* Discoid, thick, with convex whorls and a rounded margin, tuberculated and ribbed; whorls half exposed, about 4, their inner margin smooth; tubercles large, near the middle of the sides of the whorls, about 12 in each whorl; ribs prominent, rounded, 3 or 4 from each tubercle and sometimes an intermediate one; aperture nearly circular, completed 3 or 4 times in each whorl with a thickened edge. Diameter 2½ inches, thickness 1 inch. Figured of the natural size.

Loc. near Charee.

Fig. 11. *Ammonites ignobilis.* Discoid, depressed, umbilicated, keeled, radiated; front rounded with a slightly prominent entire keel; umbilicus small, with squarish edges, exposing a small portion of the inner whorls; radii covering half the whorl, in pairs or forked, commencing and terminating with obscure tubercles, waved; aperture sagittate, narrow. Diameter nearly 3 inches, thickness 10 lines. Length of the aperture 1¼ inch. Drawn of the natural size.

Loc. near Charee.

Fig. 12. *Ammonites corrugatus* (M. C. t. 451, f. 3)? An imperfect specimen, rather more strongly ribbed than the one figured in Mineral Conchology. Drawn of the natural size.

Loc. near Charee.

Fig. 13. *Ammonites Armiger.* Discoid, inner volutions exposed; inner whorls radiated and furnished with a row of tubercles on their sides; outer whorl with a row of tubercles near the inner edge, and a row of spines near the outer edge on each side,—the tubercles and spines connected by thick ribs; margin flat; aperture oblong, squarish. Diameter 7 inches. The figure is reduced one-half.

Strongly resembling *A. perarmatus* (M. C. t. 352), but the whorls increase more rapidly in size, and the aperture is longer. Probably *A. Catena*, *A. perarmatus*, and this are only varieties of one species.

Loc. near Charee.

Figs. 14, 15, 16. *Crinoidal stems*, apparently of 3 species.

Loc. near Charee.

Plate XVIII.

(Fossils from the Nummulitic Limestone and Marl, Cutch, p. 414.)

Fig. 1. *Cardium intermedium.* This shell, of which we have only casts, is very near in form to *Cardita intermedia* of Lamarck; the hinge, as we learn from the impression, however, wants the long marginal tooth, which marks the genus *Cardita.* Length 1 inch, width the same.

Loc. Baboa Hill.

Fig. 2. *Cardium ambiguum.* The furrows upon the surface of this cast are deeper than they would be in a cast from the European *C. serratum;* which, in the general form of the shell and number of furrows, it resembles more strongly than it does the *C. lævigatum* of the Indian Seas. Length 2 inches 1 line, width 1 inch 10 lines. Drawn two-thirds of the natural size.

Loc. Baboa Hill.

Fig. 3. *Arca hybrida.* Transversely oblong, oblique, longitudinally costated; costæ strongly marked with the lines of growth,—those on the anterior side, furrowed along the middle; area narrow. Length 11 lines, width 14 lines.

Nearly related to the recent *A. rhombea,* but with a narrower area between the beaks, approaching to *A. Indica* of Linnæus.

Loc. Baboa Hill.

Fig. 4. *Pectunculus Pecten.* Orbicular, convex, ribbed; ribs about 30, radiating, crenated by the lines of growth; hinge-line short. Length 10 lines, width 11 lines.

Very nearly like *P. pectinatus* of Lamarck, but with more numerous and more distinctly granulated rays.

Loc. Baboa Hill.

Fig. 5. *Nucula Baboensis.* Transversely oval, convex, smooth? ; lunette sunk; beaks nearest the anterior side. Length ¾ inch, width 1 inch.

Nearly resembling *N. Bowerbankii* (Geol. Trans. 2nd series, vol. v. 136, Pl. 8, f. 11), but not truncated or pointed below the lunette.

Loc. Baboa Hill.

Fig. 6. *Pecten lævi-costatus.* Short, smooth, radiated; radii about 20, large, equal to the spaces between them; ears large; inside furrowed. Length 1 inch 4 lines.

Length a little less than the width, but the ears enter so much into the sides that they confine the beaks into a small angle, and make the form appear more transverse than it really is.

Loc.

Fig. 7. *Ostrea callifera.* (Lam. Hist. Nat. vol. vi. p. 218. Deshayes, Coq. Fossiles des Env. de Paris, vol. i. 339. Pl. LI., f. 1, 2.)? A very ponderous shell with only a shallow cavity for the animal. Length 3½ inches, width 2¾ inches, thickness of the shells above an inch and a quarter.

The figure is reduced to two-thirds of the natural dimensions.

Loc. Wagé-ké-pudda.

Fig. 8. *Ostrea orbicularis.* Orbicular, plaited; both valves convex; plaits angular, repeatedly forked; surface imbricated. Length and width about two inches, resembling *O. Flabellulum,* but more regularly and finely striated. See p. 416.

Loc. Luckput.

Fig. 9. *Neritina grandis.* Short-conical, smooth; spire concealed; aperture very large; base convex, its margin rounded. Diameter 3 inches, height 1½ inch, Reduced in the figure to two-thirds the diameter.

This resembles *N. Schmidelliana,* but has a larger aperture in proportion and a less excentric apex; it is also higher. The specimen is little more than a cast, and does not exhibit the edge of the inner lip, but still it shows the attachment of the ligament projecting from the lower surface, and that the aperture occupied more than half the base.

Loc. Wagé-ké-pudda.

Fig. 10. *Globulus obtusus.* Globose, with a very short spire; whorls about 6; aperture ovate-elongated, pointed above; umbilicus open, narrow. Height 1 inch, diameter the same.

The short spire of 5 whorls gives this shell a very blunt aspect.

Loc. Baboa Hill.

Fig. 11. *Turbinellus bulbiformis.* Short-fusiform, smooth; spire pointed; whorls 6, flattened in the middle; aperture narrow, pointed at both ends. Height above 7 inches, diameter 5 inches. Reduced to half its size in the figure.

Resembles *T. Napus,* but has a more elongated spire.

Loc. Wagé-ké-pudda.

Fig. 12. *Cypræa depressa.* Obovate, with a blunt spire and a flattened space across the middle of the back. Length 3½ inches, width 2 inches 7 lines. Drawn one half its size.

This being only a cast, we can give but a very imperfect description.

Loc. Baboa Hill.

Figs. 13, 13 *a.* *Nummularia acuta.* Depressed, sides conical, decreasing in proportional height by age; when young radiated, when full-grown granulated; volutions and septa numerous; edge sharp. Diameter 5 lines, thickness 1½ line.

Distinguished from most other species of Nummularia by the conical form of the sides. Fig. 13 *a* is a vertical section magnified.

Loc. Luckput.

Figs. 14, 14 *a.* *Nummularia obtusa.* Irregularly orbicular, thick, smooth, sides flattened; margin rounded; volutions and septa very numerous. Diameter of the largest individual 10 lines, thickness nearly five lines. Fig. 14 *a* is a part of a vertical section magnified. A remarkably thick species.

Loc. Wagé-ké-pudda.

Figs. 15, 15 *a,* & 15 *b.* *Lycophris Ephippium.* Orbicular, depressed, curved so as to resemble a saddle, with a gently elevated umbo on each side; margin thick, obtuse, with a narrow waved keel in the middle, grains on the surface small and equal. Diameter 1½ inch, thickness 3 lines.

Fig. 15. A full-grown individual, showing by a break that it is composed of two plates; fig. 15 *a,* a portion of the surface magnified; fig. 15 *b,* a portion of a vertical fractured section, and the inner surface of one of the plates magnified.

Figs. 16, 16 *a,* & 16 *b.* *Lycophris dispansus.* Lenticular, thick, with a very thin, expanded, sharp-edged margin; grains on the surface largest in the centre of the disk. Diameter ½ an inch.

Fig. 16. A group, natural size; fig. 16 *a,* vertical section magnified; fig. 16 *b,* a horizontal section magnified.

These two fossils may possibly be different stages of growth of the same species; for there occur along with them many curved plates which are intermediate in form. The grains on the surface are the projecting extremities of internal columns, not merely granulations in the substance of the fossil, as in some species of Nummularia. The internal structure is totally different from that of Nummularia, as it is only on the inner surfaces of the two plates (fig. 15 *b*) that any appearance of a spiral or concentric series of cells can be traced. In p. 415 these fossils are assigned to the genus *Orbitolites*.

Loc. Both species very abundant at Baboa Hill and Wagé-ké-pudda.

Figs. 17, 17 *a*. *Fasciolites* (Parkinson) *elliptica*. Elliptical with blunt extremities, bands curved. Length $5\frac{1}{2}$ lines, diameter 3 lines. Fig. 17 *a* is magnified twice.

Several species of this genus occur in the tertiary formations of Europe, but they are longer in proportion to their thickness.

Loc. Wagé-ké-pudda and Baboa Hill.

The following species of Echinodermata are all reduced in the engraving to half their dimensions.

Fig. 18. *Echinus dubius*. Orbicular, depressed; areæ granulated, concave, and nearly free from grains along the middle; the larger furnished with two rows of tubercles near each side; the lesser with one row on each side; pores of the ambulacra in numerous, arched rows. Diameter about 3 inches, height about $1\frac{1}{4}$ inch.

This has apparently imperfect tubercles, and is much longer than *Cidarites variolaris*, Brongn., which, however, it much resembles.

Loc. Baboa Hill and Wagé-ké-pudda.

Fig. 19. *Galerites pulvinatus*. Orbicular, depressed, spheroidal, covered with minute tubercles. Ambulacra obscure beneath, crossed by grooves above. Diameter $3\frac{1}{4}$ inches, height 1 inch 10 lines.

A species much like *G. depressus*, Lam., but more convex and ten times the size of it.

Loc. Baboa Hill.

Figs. 20, 20 *a*. *Clypeaster affinis*. (Goldfuss, p. 134, t. 43. f. 6)? Our specimen appears to be more orbicular than the *C. affinis* of Goldfuss, but it is too imperfect to be determined,—the posterior half being nearly all broken away. Length about $2\frac{1}{4}$ inches, width 2 inches, height 1 inch.

Fig. 20 *a* is a magnified view of part of the surface.

Loc. Baboa Hill.

Figs. 21, 21 *a*. *Clypeaster varians*. More or less obovate, hemispherical; base slightly concave in the middle; ambulacra elongated; anus transverse. Length $2\frac{1}{2}$ to 3 inches, breadth 2 to $2\frac{1}{2}$ inches, height $1\frac{3}{4}$ to 2 inches.

Fig. 21 *a*. Portion of the surface magnified.

C. Bonei of Munster (Goldfuss, 131, t. 41, f. 7) resembles this, but is more depressed, and has a circular anus.

Loc. Baboa Hill and Wagé-ké-pudda.

Figs. 22, 22 *a* & *b*. *Spatangus obliquatus*. Gibbose; emarginate at the front; behind obovate, rather acuminated, and truncated obliquely upwards. Ambulacra deeply sunk in 3 large and 2 smaller ovate pits; base slightly convex. Length $2\frac{1}{2}$ inches, width 2 inches, height $1\frac{1}{2}$ inch.

Fig. 22 *b* is a magnified tubercle.

Strongly resembling *S. Bucklandii* (Goldfuss, 154, t. 47, f. 6); it is, however, much larger, and has unequal ambulacra. In this and the allied species with concave ambulacra there is a reticulated band surrounding the ambulacra, which deserves attention. (See fig. 22 *a*.)

Loc. Baboa Hill.

Figs. 23, 23 *a*. *Spatangus acuminatus* (Goldfuss, 158, t. 49, f. 2).? Our specimen is not quite so much elevated posteriorly as the figure given by Goldfuss, neither is it quite so wide; in both these circumstances it approaches to *S. lacunosus;* but it is laterally crushed, which may account for the difference. Length 1¼ inch, width nearly the same, height 10 lines. A magnified view of the surface is given at fig. 23 *a*.

Loc. Baboa Hill.

Fig. 24. *Spatangus elongatus*. Elongated, ovate, depressed; front emarginate; base convex; ambulacra concave, with two of the rows of pores nearly central; apex excentric; mouth remote from the margin. Length nearly 2½ inches, width 1¾ inch, height 1 inch.

The two posterior ambulacra and the posterior portion of the shell are broken; the description is therefore incomplete.

Loc. Baboa Hill.

Figs. 25, 25 *a*. *Clypeaster oblongus*. (*C. scutiformis?* Lam.) Oblong, subpentagonal, convex above, concave beneath; ambulacra very broad, obtuse. The surface magnified is shown at fig. 25 *a*. Length 2¾ inches, breadth above 2 inches, height 7 lines.

The specimen is too much mutilated to show the anus. It is more pentagonal than *C. scutiformis*, to which we have before referred it.

Tertiary Formation. Loc. Between Joongrea and Kotra.

Figs. 26, 26 *a*. *Clypeaster depressus*. Pentagonal, much depressed; ambulacra oval; anus very near the margin (see fig. 26 *a*). Length in the oldest individual about 2 inches, breadth rather less, height about ½ inch.

This differs from *C. Laganum* in the position of the anus, which in that species is half-way between the mouth and the margin, in the greater size of the papillæ, and in being much thinner.

Tertiary Formation. Loc. Soomrow.

Plate XIX.

(Fossils from the Tertiary Formations, Cutch.)

Fig. 1. *Serpula? recta*. An oval, free, slightly-waved shelly tube, which we have provisionally called a *Serpula*, although it is more like the tube of a *Teredo;* but it appears to have been formed in loose sand. Diameter ¾ inch.

Loc. near Kotra.

Fig. 2. *Siliquaria Grantii*. Spirally striated; striæ crossed by numerous cracks; fissure composed of a series of oval pores. It differs from the recent *S. anguina* only in the smallness of the pores which form the fissure.

Loc. Borders of the Runn.

Fig. 3. *Balanus sublævis*. Subcylindrical with curved valves, nearly smooth. Operculum? Diameter 1 inch, height 9 lines. Parasitic upon shells.

Loc. Soomrow.

Fig. 4. *Corbula trigonalis.* Trigonal, with the front rounded, gibbose, antiquated; valves nearly equal, posterior side truncated obliquely with a carina upon each valve, and pointed; umbones equal, central. Length 6 lines, width 8 lines; but these proportions vary.

Loc. Borders of the Runn.

Fig. 5. *Corbula rugosa* (Lam. vol. v. 497). This differs from the last in being a much wider shell, with more regular and prominent laminæ upon the surface. Length 2½ lines, width 3½ lines.

Loc. Borders of the Runn.

Fig. 6. *Tellina exarata.* Ovate, compressed, ornamented with many erect concentric laminæ; the posterior extremity pointed, much bent. Length nearly ¾ of the width, which is nearly 2 inches.

Strongly resembling *Tellina virgata* (Lam. His. Nat. vol. v. 52), but wider and more bent.

We have ventured (contrary to our usual custom) to complete the surface of this shell, although much has been lost from the specimen.

Loc. Toomrow.

Fig. 7. *Venus granosa.* Obovate, truncated, posteriorly convex, ornamented with erect concentric laminæ, crossed by numerous striæ which cut these (near the margin) into rounded grains; lunette broad, pointed, convex; beaks nearest the anterior extremity. Length 1¾ inch, width more than 2 inches.

This belongs to the same family of *Venus* as *V. Corbis*, and *V. puerpera*, and is scarcely distinguishable from *V. puerpera*, β (Lam. Hist. Nat. vol. v. 585).

Loc. Soomrow.

Fig. 7.* *Venus cancellata.* Obovate, approaching orbicular, gibbose, ornamented with erect concentric laminæ, and many longitudinal striæ; lunette wide, pointed, convex; beaks nearest the anterior extremity. Length 1¾ inch, width 1 inch 11 lines.

This resembles the last, except that it is rounder, with thinner laminæ, which are not cut into round grains.

Loc. Soomrow and Kotra.

Fig. 8. *Venus non-scripta.* Transversely oval, convex, smooth, concentrically undulated; lunette elongated, pointed, concave; beaks nearer the anterior extremity. Length 1 inch 4 lines, width 1¾ inch.

A smooth and thin shell, with little of the aspect of a Venus.

Loc. Soomrow.

Fig. 9. *Pullastra? virgata.* Transversely oval, elongated, decorated with smooth concentric ridges; beaks nearest the anterior extremity. Length 13 lines, width 1 inch 7 lines.

Several recent species of *Pullastra* are like this, but no described one appears to be identical with it.

Loc. Soomrow.

Fig. 10. *Cardita intermedia* (Lam. Hist. Nat. vol. v. part 1, 23; Brocchi, vol. i. 520, t. 12, f. 15).? This strongly resembles several species of *Venericardia*, Lamk.

Loc. Soomrow.

Fig. 11. *Cardium triforme.* Orbicular, ventricose, longitudinally striated; anterior side covered with round granules formed by decussating striæ; the

posterior side crossed by oblique sets of reflected ridges. Length and width 1 inch 4 lines.

Somewhat resembling the recent *Cardium æolicum.*

Loc. Soomrow.

Fig. 12. *Arca radiata.* Transversely elongated, oblique, rather convex, radiated; radii elevated, furrowed; beaks almost close, nearest the anterior side. Length 7 lines, width 1 inch.

Loc. Soomrow.

Fig. 13. *Arca tortuosa ?* Linn. This is only a fragment, and what there is seems to differ from the recent *Arca tortuosa* in the degree of curvature.

Loc. Soomrow.

Fig. 14. *Pecten Soomrowensis.* Obovate, convex, radiated; radii about 24, squamose, subdivided, in one valve into 3, in the other into 5; ears unequal, striated, and squamose. Length 2 inches 2 lines, width nearly 2 inches.

In form this *Pecten* approaches to *P. varians,* but in the structure of the surface it is like *P. plebeius* of the Crag, and many recent species. We have given a magnified figure of part of the surface of the opposite valve.

Loc. Soomrow.

Fig. 15. *Pecten articulatus.* Orbicular, with pointed beaks, depressed, radiated; radii about 28, simple, rounded, crossed by distant scales; ears large, striated, and squamose. Length in an old specimen about 1 inch 8 lines, width 1 inch 6 lines. We have figured a small specimen.

The radii when the scales are worn off appear jointed.

Loc. Bank of the Runn.

Fig. 16. *Gryphæa globosa* (M. C. t. 392. *Ostrea vesicularis,* Lam. Hist. Nat. vol. vi. part 1, p. 219. Cuv. and Brongn. Env. de Paris, 383, t. 3, f. 5. *Podopsis gryphæoides,* Lam. Hist. Nat. vol. vi. part 1, 195).

This exactly agrees with old specimens found in the chalk of Norfolk.

Loc. Kotra.

Fig. 17. *Ostrea angulata.* Suborbicular, arched, compressed, plaited; plaits angular, numerous, branched towards the margin; laminæ of increase regular, distant, raised at their edges. Length about 1¼ inch, width the same.

Loc. Kotra.

Fig. 18. *Ostrea Flabellulum* (M. C. t. 253, Lam. Hist. Nat. vol. vi. part 1, 215. *Chama plicata,* Brander, 84 and 85). The identity of this oyster with the *O. Flabellulum* of the tertiary formations of Europe is unquestionable.

Loc. Cheeosir.

Fig. 19. *Ostrea tubifera.* Orbicular; laminæ of increase thick, raised into a few large, nearly erect tubes arranged in about 6 rows. Diameter 2 inches.

Loc.

Fig. 20. *Ostrea Lingua.* Much elongated, smooth, approaching to even; upper valve flat or concave, the other very convex; squamoso-fimbriated at the edges. Length 2½ inches, width 1½ inch.

So variable are *Ostreæ* in form, and so much do the species resemble each other, that it is hardly possible to define some of them clearly. That before us is very like *O. tenera* (M. C. t. 252, f. 2. and 3), yet in the depth of the attached valve it approaches to *O. Meadii* (M. C. 252, f. 1 and 4), but is not waved like that.

Loc. near Joonagrea and Kotra.

Plate XX.

(Fossils from the Tertiary Formations, Cutch.)

Fig. 1. *Bulla lignaria*, Linn. This agrees perfectly with the recent species as far as we can ascertain from specimens which are not perfect ; but it is quite distinct from both the fossil shells described by Deshayes under the same name.

Loc. Soomrow.

Fig. 2. *Natica obscura.* Globose, umbilicate ; spire small, pointed ; whorls about 5, convex, flattened, and ornamented at the upper edge with fine diverging plaits ; umbilicus partly filled with a semi-cylindrical, obliquely-truncated callus. Height $1\frac{1}{4}$ inch, diameter the same.

Nearly related to *N. Epiglottina*, Lam., but distinguished by the flattened upper margins of the whorls ; and to *Nerita canrena* of Brocchi, vol. ii. 296.

Loc. Soomrow.

Fig. 3. *Natica callosa.* Obliquely depressed ; spire small, hardly projecting ; umbilicus covered by the thickened and expanded inner lip ; aperture very large. Height 2 inches, diameter $1\frac{3}{4}$ inch.

A very distinct species.

Loc. Soomrow.

Fig. 4. *Globulus ? anguliferus.* Oblong, obliquely striated ; spire produced ; whorls about 4, with their sides and upper edges flattened ; umbilicus open, rather large. Height and diameter $\frac{3}{4}$ inch.

The elevated lines or striæ advancing towards the aperture as they descend the sides of the whorls form a peculiar character. The aperture appears to be small.

Loc. Borders of the Runn.

Fig. 5. *Solarium affine.* Convex above, flattish beneath, marked with diverging striæ on both sides ; whorls 4 or 5, with a deflected entire carina, above which are 4 furrows placed at nearly equal distances, and below, 2 furrows near the carina, and 2 near the umbilicus, which is large, with a crenated edge. Diameter $1\frac{1}{2}$ inch, height $\frac{1}{2}$ inch.

Perfectly distinct from *Solarium perspectivum*, which it somewhat resembles.

Loc. Soomrow.

Fig. 6. *Trochus cognatus.* Conical with straight sides ; whorls numerous, ornamented with several rows of granules, which sometimes (especially towards the apex) are united by elevated lines, and a row of tubercles upon the inferior edges of the upper whorls, succeeded by 2 rows upon the middle volutions, and crenated ridges of slight elevation on the rounded border of the lowest whorls ; base flat, concentrically furrowed, containing a thick plait within.

Like *T. maculatus ;* height 2 inches, diameter of the base nearly the same.

Loc. Soomrow.

Fig. 7. *Turritella angulata.* Turrited, conical ; whorls convex, decorated by about 7 carinæ, of which the lowest but one is much the most prominent. Height $1\frac{1}{2}$ inch, diameter 8 lines.

Loc. Soomrow.

Fig. 8. *Turritella assimilis.* Turrited, whorls convex, ornamented with 6 or 7 carinæ, of which 2 or 3 are obscure, the 2nd and 5th being prominent. Height $1\frac{1}{2}$ inch, diameter 5 lines.

A smaller, narrower species than the last.

Loc. Soomrow.

Fig. 9. *Terebra reticulata.* Subulate; sides of the whorls flat, cancellated; a narrow upper portion of each whorl divided from the lower in the form of a band by a ridge and furrow; beak short, curved.

In some specimens the transverse or spiral lines are less conspicuous, particularly on the band and the upper half of the whorl.

Loc. Soomrow.

Fig. 10. *Cerithium rude.* Subulate, with curved sides, ribbed and furrowed; ribs numerous, cut across by about 5 square furrows, of which the uppermost is distant from the suture; whorls 10 or 12, nearly flat, with an obtuse varix between each—the last varix very prominent; aperture nearly round, with a canal at the upper angle; inner lip thick, with a callus at the top; beak broken. Height 2 inches 8 lines, diameter about 8 lines.

Loc. Soomrow.

Fig. 11. *Cerithium corrugatum.* Subulate, ribbed, and coarsely striated; ribs numerous, arched, and prominent, crossed by deep striæ; whorls 8 or more, rather convex, with a distinct varix upon each.

This has much of the contour of an elongated Fusus. The lip and beak are wanting in the only specimen found.

Loc. Soomrow.

Fig. 12. *Fusus ? granosus.* Short-fusiform, ribbed; ribs about 12 upon each whorl, divided into grains by 6 or 7 transverse ridges, convex; spire half the length of the shell; beak suddenly contracted. Height 4 lines.

A pretty shell, much resembling some species of *Nassa* which occur in the Crag.

Loc. Soomrow.

Fig. 13. *Fusus læviusculus.* Short, fusiform, ribbed, and striated; ribs irregular, mostly very short; whorls 6, angular; base conical; beak short. Height 10 lines, diameter 5 lines.

Loc. Soomrow.

Fig. 14. *Fusus nodulosus.* Fusiform, elongated, ribbed and strongly striated; ribs short, broad, about 8, in the middle of each whorl; whorls 6 or 7, concave above, convex below; beak contracted.

Loc. Soomrow.

Fig. 15. *Fusus (Murex ?) hexagonus.* Short-conical, with an elongated beak, 6-angled; whorls about 6, with 6 ribs on each, which form the angles of the spire, and are crossed by 3 strong ridges upon the spire, thickened where they cross, convex; beak suddenly contracted.

Loc. Soomrow.

Fig. 16. *Ranella Bufo.* Conical, with 2 rows of thin expanded varices and several ribs, the whole crossed by 3 or 4 prominent and several intermediate thin ridges; whorls 7 or 8, convex; varices obtuse at their edges; aperture oval; beak short, oblique. Height 1 inch 4 lines, diameter 1 inch.

Nearly resembles *Ranella bituberculata* of Lamarck.

Loc. Soomrow.

Fig. 17. *Rostellaria rimosa* (M. C. 91, f. 4, 5, 6, *Strombus cancellatus,* Lam. Hist. Nat. vol. vii. t. 212). ?

The fragment we have before us is firmly imbedded in the stone, and we are not able to clear the lip so as to ascertain whether it be striated like the lip of the recent *Strombus cancellatus,* Lam., or smooth and thickened as in *Rostellaria*

rimosa and *R. Fissurella*, Lam., &c.; of all these, the species nearest to the fossil is *R. rimosa* of the London Clay, which is easily distinguished from *R. Fissurella*, Lam., of the Paris Basin, by being striated all over, and having the canal continued nearly to the apex of the spire, but not curved back. From *Strombus cancellatus*, Lam., this fossil is distinguished by having a tumid varix upon the last whorl, a character also of *Rostellaria rimosa*, and we are consequently induced to refer the Cutch shell to it rather than to *Strombus cancellatus*.

Linnæus and his immediate followers did not distinguish between the recent and fossil shells, although the recent one (*Strombus decussatus*, Lam.) has the lip striated within, and is placed by Lamarck in another genus, while Deshayes, in the "Coquilles fossiles des Environs de Paris," unites the French fossil and the two English ones under one name, although they are perfectly distinct; probably he has not examined English specimens. We find the characters very constant, and easily observed when once pointed out. The analogous shells of Bordeaux are equally distinct. About the same size as *R. rimosa*, M. C., from Barton.

Loc. Soomrow.

Fig. 18. *Rostellaria rectirostris*. (Lam. Hist. Nat. vol. vii. 192.) The elongated form induces us to refer this fossil to the recent *R. rectirostris*, in preference to any other species.

Loc. Soomrow.

Fig. 19. *Strombus deperditus*. Turbinate, tuberculated and transversely striated; tubercles united by a slight carina gradually increasing in size; lip thickened, produced above into a short pointed lobe. Height 2¼ inches, diameter 1 inch 4 lines, including the wing.

Much like *Strombus Gallus*, Linn., and *S. bituberculatus*, Lam., but the tubercles are of an equal size on the last whorl and not much larger than on the spire. The aperture is not much dilated, so that the wing is rather small. It appears to be a very common shell in the Runn, but perhaps there are several species, as many of the specimens are so firmly attached to the stone, and so much concealed, that the distinguishing marks cannot be traced.

Loc. Soomrow.

Fig. 20. *Strombus nodosus*. Turbinate, elongated, tuberculated, transversely and longitudinally striated; tubercles equal, numerous, prominent, obtuse. Height 1¾ inch.

Distinguished by the rounded tubercles, of which there are about 12 to each whorl—and the elongated spire.

Rare—we have seen but one specimen, and that is very imperfect.

Loc. Soomrow.

Fig. 21. *Cassis* (*Cypræcassis*, Stutchbury) *sculpta*. Ovate, transversely sulcated; aperture narrow, the outer lip plaited, the inner smooth. Height 1¾ inch, diameter 1 inch.

Strongly resembling *Cassis* (*Cypræcassis*, Stutchbury) *Testiculus* (*Bucc. Testiculus*, Linn.), but smoother, and with a narrower aperture.

Loc. Soomrow.

Fig. 22. *Turbinellus affinis*. Subfusiform, swelled in the middle, ornamented with many transverse ridges and a row of flattened tubercles near the upper margin of each whorl; beak produced transversely, ribbed; columella 5-plaited. Height 4 inches, width 2 inches.

Very nearly related to *Turbinellus scolymus*, Lam., but it is more elongated, has smaller tubercles, and 5 not 3 plaits on the columella.

Loc. Soomrow.

Fig. 23. *Mitra scrobiculata* (Brocchi, vol. ii. 317, t. iv. f. 3).? This is the same as the fossil found at Piacenza. It is often larger than our figure.

Loc. Soomrow.

Fig. 24. *Mitra fusiformis*. Fusiform, pointed, striated; striæ distant, deep, punctated, suture entire; columella with 4 plaits. Height 2 inches, diameter 9½ lines. Somewhat resembling *Mitra adusta* of Lamarck.

Loc. Soomrow.

Fig. 25. *Volupta jugosa*. Fusiform, pointed, transversely striated, costated; costæ many, rounded, terminating in points above the suture; aperture elliptical, elongated; columella with 3 plaits. Height 2½ inches, diameter 1¼ inch.

This differs from *V. Magorum* of Brocchi, in the form of the ribs, and the small number of plaits upon the columella, and from *V. costata* (M. C. t. 290), in the form and in the greater number of the ribs.

Loc. Soomrow.

Fig. 26. *Voluta dentata*. Turbinate, striated, spire short, conical pointed; whorls crowned with tubercles which surround a concave space; aperture elongated; the outer lip thick, crenato-dentated within. Height 1 inch 7 lines, diameter 1 inch.

Loc. Soomrow.

Fig. 27. *Cypræa humerosa*. Obovate, depressed with 3 protuberances upon the back, and one on each side. Length 2 inches, width 1½ inch.

Loc. Soomrow.

Fig. 28. *Cypræa Prunum*. Oval, ventricose; aperture narrow, slightly curved with about 20 teeth on each side; base convex; beak small, not much produced; a very even shell. Length nearly 2 inches, width 1¼ inch.

Loc. Eyerau.

Fig. 29. *Cypræa digona*. Ovate, ventricose, slightly depressed; base flattened on each side; beak expanded, prominent, with sharp edges; teeth on each side the aperture, above 20. An obscurely-marked species. Length 13 lines, width 9½ lines.

Loc. Soomrow.

Fig. 30. *Cypræa nasuta*. Ovate-elongated, ventricose; beak projecting, large; posterior extremity of the lip produced; apex of the spire sunk. Length 10 lines, width 6 lines.

Loc. Soomrow.

Fig. 31. *Terebellum obtusum*. Ovate, much elongated; spire 2 or 3 whorls, obtuse. Length about 2 inches, width 6 lines.

This is more like the recent *T. subulatum* than the fossil *T. fusiforme*.

Loc. Soomrow.

Fig. 32. *Oliva Pupa*. Elongated, subcylindrical, with a produced pointed spire, a broad smooth band at the base, and a slightly-plaited callus on the columella. Length 1 inch 9 lines, width 8 lines.

Loc. Soomrow.

Fig. 33. *Conus brevis*. Short-conical; spire flat, with a produced apex marked with 4 concentric striæ decussated by the lines of growth; base ornamented with several small, rather distant ridges. Height 1¼ inch, diameter 1 inch.

Imperfect specimens are found, more than double the diameter of the figure.

Loc. Soomrow.

Fig. 34. *Conus militaris.* Conical, elongated, slightly contracted towards the edge of the spire, coloured by many triangular spots arranged in zigzag rows; spire flat, upper surfaces of the volutions concave; base nearly smooth. Height 1½ inch, diameter 11 lines.

This shell and the following retain traces in a remarkable manner of the original colouring.

Loc. Soomrow.

Fig. 35. *Conus catenulatus.* Conical, elongated, coloured with transverse rows of white spots upon a dark ground—spire flat, elevated in the middle; concentrically striated, mottled with white, the edge sharp; the base obscurely furrowed. Length 1¼ inch, width 8 lines.

Loc. Soomrow.

Fig. 36. *Conus marginatus.* Conical, much elongated; spire conical, short, surrounded by an obtuse ridge from its base to its apex; base of the shell striated. Length 1½ inch, width 8 lines.

Loc. Soomrow.

Plate XIV.

Wood-Cuts [*in orig.*].

Fig. 1. Section of the elevated plateau of nummulitic limestone on which is situated the town of Luckput, referred to p. 415.

Fig. 2. Dike of basalt intersecting and throwing off the strata of slate-clay and sandstone, in the river near Jauntra, ditto p. 422.

Fig. 3. Bank of the river near Jarra on the borders of the Runn, exhibiting the different effects produced on laminated and compact strata by disturbing forces, ditto p. 422.

Fig. 4. Diagram of alternations of Basaltus with Travertin, ditto p. 427.

Fig. 5. End view of one of the natural walls of the Runn, ditto p. 435.

Figs. 6, 7, 8, 9. Four views of natural walls of the Runn, ditto p. 435.

Fig. 10. Wall of Sandstone near Rampoora, ditto p. 435.

A Notice respecting some Fossils collected in Cutch by Captain Walter Smee, of the Bombay Army. By Lieutenant Colonel W. H. Sykes, F.R.S., F.G.S.*†

[Read March 26th, 1834.]

In exhibiting to the Geological Society some interesting fossil shells, collected in Cutch by Captain Smee, of the Bombay Army, I have to

* This paper was read previously to that by Captain Grant on Cutch, printed in the second part of the volume, and the delay in its publication has been owing to various causes which it is unnecessary to state.

† Reprinted from the Transactions of the Geological Society of London, vol. v. p. 715; second series.—Ed.

make my acknowledgments to Mr. James de Carle Sowerby for his assistance in determining the various specimens. The locality from which they were obtained is in the province of Choorwaugur, between the 23rd and 24th parallels of north latitude, and the 70th and 71st degrees of east longitude. On the east and north it is bounded by the celebrated Runn, a tract of low lands, one part of which is periodically overflowed, another is salt marsh, and a third sandy desert; and, extending from the mouths of the Indus to the head of the Gulf of Cutch, it gives the country an insular character.

I shall confine the notice to a few short remarks on the specimens.

Of *Ammonites* there are several species, and one of them bears so close a resemblance to *A. Harveyii* of the oolitic series of England, that Mr. Sowerby cannot satisfy himself that there is any difference (see fig. 15, Pl. XXI.). The new species are figured in Plate XXI. The whole of the specimens were obtained from the red rock in the neighbourhood of Shahpoor and Kuntkote.

Trigonia.—Imbedded in the mouth of *Ammonites Harveyii* (fig. 15, Pl. XXI.) is apparently a young specimen of *Trigonia costata*, a shell characteristic of the oolitic rocks of England.* Another species, which Mr. Sowerby considers to be new, I have named after Captain Smee. It occurs in the water-courses and the ploughed fields about Shahpoor, but the specimens do not appear to have been water-worn. (See Pl. XXI. fig 5.)

Astarte.—Of this genus Mr. Sowerby has determined two new species. They were met with under similar circumstances to the *Trigoniæ* (figs. 1 and 2).

Corbula.—An undescribed species occurs abundantly in an indurated ferruginous rock at Dookurwarra in the Runn, at the north-east point of Cutch, in the 71st degree of longitude. The strata are highly-inclined and very thin, and transverse sections of the slabs present a beautiful appearance. It is not associated with the other shells.

Gryphæa.—A specimen belonging to this genus so closely resembles the *Gryphæa dilatata* of the Oxford clay of England, that Mr. Sowerby has not been able to separate specifically the Cutch fossil from it. (See fig. 16, Pl. XXI.) Other specimens, varieties apparently of this shell, occur in Captain Smee's collection, and differ in the back of the lower valves being more convex and the beak more prominent. They were all found under the same circumstances as the *Trigoniæ*.

Captain Smee's series also contains specimens of *Lycophrys*,† presented to him by Dr. Burnes of the Booj Residency. They are said to

* A full-grown shell of this species is given in Pl. XV. fig. 16, of the illustrations to Captain Grant's Memoir.

† See Pl. XVIII. figs. 15 and 16, Captain Grant's illustrations.

be thrown up in ridges near Luckput Bunder. In addition to the shells, the collection includes fragments of silicified fossil wood, and radiated iron pyrites similar to that contained in the chalk of England.

I have also to point out to the Society specimens of alabaster and a hard and a durable oolite from my own collection; the former from Cutch, and the latter from near Poorbunder on the west coast of the peninsula of Goojrat. This rock would appear to characterise the major part of the western portion of the province, as it is found abundantly at Raujcote in the centre of the peninsula. The oolite is used in that magnificent structure, the Town Hall of Bombay. It does not appear to resemble exactly any of the characteristic oolites of England.

Lignite.—I close the catalogue with a specimen of lignite from Cutch. Attempts were made by the government to work this coal; but whether from mismanagement or from other causes, they were not persevered in, and I believe the beds at present lie undisturbed. The locality is at the village of Tramboa, from 6 to 8 miles north of Booj. Traces of coal are also met with in many other places.

As the tracts whence the above specimens came have not been visited by a geologist, it may scarcely be prudent to speculate on the age of the formation to which they belong. If generalisations in geology in Europe be subject to exceptions, we shall run no small risk in applying European analogies to India; where we find coal occurring without the carboniferous series—a total absence of the cretaceous formation, and trap occupying whole regions without the intervention of any sedimentary rock, and without the appearance of modern or even ancient volcanos. Were we to judge of the NW. coast of India in the neighbourhood of the localities of the above specimens, from its general flatness, its salt marshes, and the extent of the Runn, we might consider it as recently emerged from the ocean, and comparatively modern fossil shells might have been looked for. The inhabitants, indeed, consider the surface of inland water as gradually contracting, and the period may arrive when the Runn shall disappear. If English analogues be our guide, the fossil specimens I have submitted to the Society would seem to belong to the secondary rocks; *Ammonites, Trigoniæ, and Gryphæa* have been found only in formations below the tertiary systems,—we may not therefore err in considering the formations of Cutch to be secondary. Quarries of fine crystallised marble are found at Nuggur Parker on the north bank of the Runn.

The strata of Cutch have been much disturbed by the intrusion of igneous rocks, which in fact are the highest in the country, and it is still subject to earthquakes. The country furnishes an abundant supply

of iron ore. It is much to be regretted that the East India Company have not deputed a scientific person to examine Cutch and Goojrat, as the cost of the undertaking would very probably be amply repaid by the discovery of their mineral treasures; and a yet higher advantage would be obtained in the light which would be thrown on the history of the earth.*

NOTE.—*November 4th*, 1837.

When the specimens alluded to in the preceding notice were first submitted to the examination of the Society, the unexpected resemblance which some of them were found to bear to English oolitic fossils gave rise to doubts whether English shells had not accidentally got into Captain Smee's collection. To clear up these doubts, I wrote to my friend Colonel Pottinger,† the British Minister in Cutch, to collect for me, far and wide, all the organic remains to be met with. Colonel Pottinger, with that zeal which always characterises his prosecution of useful objects, so effectually realized my wishes, that in a comparatively short time, a large collection of fossils reached me in England; a series of these I presented to the Society, and on examination, the genuineness of Captain Smee's fossils was fully established from identical species being met with in the collection. Shortly afterwards, Captain Grant, of the Bombay Engineers, arrived from Cutch,—rich in a collection of fossils, rich in a local knowledge of the country, and doubly rich in his powers of graphic delineation. His treasures and memoranda were submitted to the Society, and I thought no more of mine. It appears, however, that independently of there being some few specimens in my collection from the field of Captain Grant's researches which he does not possess, a series of my shells comes from a territory not geologically investigated by Captain Grant, namely, the desert NE. of Cutch, from Balmeer and Joonah, and the plains and rivers in their neighbourhood, and proved by the specimens collected by Colonel Pottinger to belong to the same series of beds as those from which Captain Smee's and Colonel Pottinger's specimens were obtained in Cutch. Under these circumstances it has been thought desirable to figure the new specimens from Cutch and the Desert; and the present notice may be looked upon as an appendix to my former memoranda on Captain Smee's fossils.

* This wish has been to a very great extent fulfilled by the labours of Captain Grant, 1839.
† Now Sir Henry Pottinger, Bart.

LIST OF FOSSILS

Contained in the collections of Captain Smee and Colonel Pottinger, determined by Mr. James De Carle Sowerby. (Plates XIV. to XIX. accompany Captain Grant's Memoir, see *ante*, p. 403.)

Genus and Species.	*Reference.*	*Locality.*
Lycophrys dispansas, Capt. Grant's Mem.	XVIII. f. 16.	Near Luckput Bunder.*
Corbula pectinata	XXI. f. 4, 4 a.	Dookenarra, in the Runn.*
Astarte major	„ f. 1.	In the neighbourhood of Shahpoor.*
—— compressa	„ f. 2.	
—— rotunda	„ f. 3, 3 a.	Hills 12 to 15 miles north of Booj.†
Trigonia costata, Min. Con. LXXXV.	Woodcut, fig. 1.	Ibid.†
—— Smecii	XXI. f. 5.	Shahpoor.*
Cucullæa virgata, Capt. Grant's Mem.	XVI. f. 1, 2. ‡	Hills 12 to 15 miles north of Booj.†
Nucula tenuistriata, Capt. Grant's Mem.	„ f. 3.	Ibid.†
Plicatula pectinoides, M. C., CCCCIX.	„ f. 6, 9 a.	Ibid.† also Desert to the NE. of Cutch.
Ostrea orbicularis, Capt. Grant's Mem.	XVIII. f. 8.	Hills 12 to 15 miles north of Booj.†
—— flabellulum, Min. Con. CCLIII.	XIX. f. 8.	Ibid.†
—— carinata ? Min. Con. CCCLXV.	XVI. f. 8.	Ibid.†
—— Marshii ? Min. Con. XLVIII.	„ f. 9.	Ibid.†
Gryphæa dilatata, Min. Con.	XXI. f. 16.	In the neighbourhood of Shahpoor.*
Terebratula dimidiata, Min. Con. XV. f. 8.	XVI. f. 15.	Hills 12 to 15 miles north of Booj; also from the Desert to the NE. of Cutch.†
—— microrhyncha	XXI. f. 7.	Hills 12 to 15 miles north of Booj.†
Fragments of a thick fibrous shell	——	
Tornatella striata	XXI. f. 6, 6 a.	Hills 12 to 15 miles north of Booj.†
Belemnites (fragments)	——	Desert NE. of Cutch.†
Ammonites Harveyii, Min. Con. CXCV.	XXI. f. 15.	Hills 12 to 15 miles north of Booj. Shahpoor or Kuntkote.*
—— Maya	„ f. 8.	Ibid.
—— calvus	„ f. 9.	Ibid.*
—— Pottingerii	„ f. 10.	Desert NE. of Cutch.†
—— fissus	„ f. 11.	Ibid.†
—— torquatus	„ f. 12.	Desert NE. of Cutch.†
—— fornix	„ f. 13.	Hills 12 to 15 miles north of Bhooj.†
Nummulites exponens	„ f. 14 a to e.	Luckput Bunder.
Fasciolites elliptica	XXIII. f. 17.	Ibid.*

* From Captain Smee's collection. † From Colonel Pottinger's collection.

‡ *C. virgata*, a young specimen, is represented in Pl. XXI. f. 6.

PLATE XXI. [LXI. *in orig.*]

Illustrates Colonel Sykes's paper on fossils procured by Captain Smee and Colonel Pottinger in Cutch and the Desert to the north-east of Cutch, p. 460. The shells have been engraved and the description prepared by Mr. James De Carle Sowerby, F.L.S.

Fig. 1. *Astarte major.* Elliptical, convex, concentrically furrowed when young; furrows numerous; beaks small, near the anterior side; lunette broad, flat, deeply sunk; ligament long, sunk. Length from 2 inches 4 lines to 2 inches 8 lines, width $4\frac{1}{2}$ inches.

This species varies much in the proportions of its length and breadth, and the anterior side is sometimes formed as if truncated. The figure represents a very wide variety diminished to $\frac{2}{3}$ its size.

Fig. 2. *Astarte compressa.* Nearly orbicular, wider than long, flattish, concentrically ribbed; lunette deep, small; beaks small, near the anterior side; edge toothed. Length $1\frac{1}{4}$ inch, width 1 inch 5 lines.

A species very closely resembling this is found at Cross Hands in Gloucestershire in the inferior oolite.

Figs. 3, 3 *a*. *Astarte rotunda.* Orbicular, concentrically ribbed; beaks central; lunette sunk; margin toothed. Length 2 lines, width the same.

Nearly like *A. elegans* (M. C. t. 137, f. 3), but it is so much imbedded in the stone that its characters cannot be clearly determined. Fig 3 *a* is magnified.

Figs. 4, 4 *a*. *Corbula pectinata.* Trigonal, rounded, gibbose, longitudinally striated, concentrically ribbed; posterior extremity separated in the form of a small lobe, pointed; ribs thin, much elevated. Lunette deeply sunk, not defined; beak incurved. Length and width nearly equal, from $\frac{1}{2}$ an inch to an inch. Fig. 4 shows the impression of the hinge-tooth.

This differs from *Corbula lyrata* (*antè* Grant, Pl. XV. f. 13), which is also from Cutch, in having numerous thin striæ and thin ribs. It occurs loose and in masses with several other shells in a red limestone.

Fig. 5. *Trigonia Smeeii.* Transversely much elongated, posteriorly truncated, convex, concentrically ribbed; the posterior surface distinguished by an obscure ridge, and furnished with twice as many ribs as the other part; ribs obtuse, seldom interrupted; beaks near the anterior extremity, which is rounded. Length 2 inches 5 lines, width 4 inches. The figure is reduced to $\frac{2}{3}$ the natural size.

Figs. 6, 6 *a*. *Tornatella striata.* Ovate, pointed, transversely punctato-striated; one obscure plait on the columella. Height $2\frac{1}{2}$ lines, diameter $1\frac{1}{2}$ line.

Much resembling *Phasianella striata* (Fitton, in vol. iv. Pl. XVIII. f. 15), but the apparent plait on the columella, if it be not the effect of fracture, distinguishes it. Fig. 6 *a* is magnified.

Fig. 7. *Terebratula microrhyncha.* Subtetrahedral, rounded, plaited, lower valve nearly flat, plaits angular, 28 or 30, of which about 9 are raised in the front; beak of the lower valve very small, its aperture inclined inwards, and its sides smooth and sunk. Length 2 inches, width $1\frac{3}{4}$ inch, depth of the valves united $1\frac{1}{2}$ inch.

A large species, distinguished from *T. nobilis* (Grant, Pl. XVI. f. 14), by the greater number of plaits.

Fig. 8. *Ammonites Maya*. Discoid convex with a rounded front, umbilicated, radiated; umbilicus conical, smooth within; radii rather numerous, slightly elevated 2, 3, or 4-partite, bent over the edge of the umbilicus; aperture rounded-sagittate with truncated angles. Diameter 7¾ inches, width of the aperture 3½ inches, its length 4 inches.

This is an intermediate species between *A. formosus* (Grant, Pl. XVII. f. 7) and *A. Herveyi* (M. C.), a variety of which also occurs with this. Its sides are flatter than in the *A. Herveyi*, although the front is round, and the ribs less raised.

Fig. 9. *Ammonites calvus*. Discoid; inner whorls two-thirds exposed, nearly crossed by rounded ribs, and plaited over their fronts; outer whorls crossed by prominent rounded ribs, their front rounded, plain; aperture oval, impressed by the preceding whorl. Diameter 7 inches, width of the aperture 1½ inch, its length 2¼ inches. A larger specimen measures 9½ inches across, and is less plaited and ribbed. The figure is drawn ⅓ of the natural size.

Very near *A. decipiens* (M. C.), but the whorls increase more rapidly and envelope each other more.

Fig. 10. *Ammonites Pottingerii*. Discoid, thick, costated; inner whorls exposed; front nearly flat; ribs sharp, prominent, split into two or three over the front; aperture transversely obovate. Diameter 4½ inches, width of the aperture 1 inch 8 lines, its length 1 inch 2 lines.

A very distinct species, cast in coarse limestone, replete with large grains of quartz.

Fig. 11. *Ammonites fissus*. Discoid, costated; whorls rapidly increasing, the inner exposed. Costæ large, obtuse, either forked or simple, with an intermediate short rib passing over the front, which is convex and prominent; aperture ovate. Diameter 4¼ inches, width of the aperture 1 inch 5 lines, its length 1½ inch; the figure is reduced to one half.

Fig. 12. *Ammonites torquatus*. Discoid, costated inner whorls exposed; costæ numerous, generally split into two as they pass over the rounded front, sometimes single, and (in large specimens) occasionally trifid; inner edges of the whorls incurved; aperture orbicular; whorls about five. Diameter 2¾ inches, width of aperture 1 inch, its length the same.

In large specimens are indications of a thickened edge having been formed to the aperture at various periods of growth. It is like *A. annulatus vulgaris* (Zieten, Pl. IX. f. 1), and also *A. colubrinus major* (*Id.* Pl. IX. f. 3), but distinguished by the incurved inner margin from both, as well as from a similar species found in the Himalaya Mountains.

Fig. 13. *Ammonites Fornix*. Discoid, compressed (when young, keeled), undulated; inner whorls ⅓ exposed, their exposed parts smooth; margin convex, smooth, with a row of minute tubercles on each side, and a slender keel, which are lost in the external whorls; undulations bent back in the middle of the sides, divided towards the margin; aperture sagittate, elliptical. Diameter 2 inches, width of aperture 7 lines, its length 1 inch 2 lines.

Figs. 14 *a* to *f*. *Nummularia exponens*. Very flat, thin, granulated, whorls few; septa rather distant, visible through the shell; chambers twice as long as deep. Diameter of the shell frequently more than an inch. *Fig.* 14 *f* is a magnified section.

When young, this *Nummulite* is lenticular; when old, it is concave in the centre.

Summary Description of the Geology of the Country between Hoshungabad on the Nerbudda, and Nagpoor, by the direction of Baitool. By Lieutenant John Finnis, 51st Regiment, Assistant Executive Officer 14th Division.*

[Presented to the Asiatic Society, 15th July 1829.]

The route between Nagpoor and Hoshungabad presents as great a variety of formations and as interesting a series of minerals, as is probably to be met with in any part of India of equal extent.

The formations exhibited are trappean, primitive, transition, and secondary, frequently under a very peculiar and confused arrangement with regard to each other, and much intersected by veins of greenstone and trap.

I regret that the circumstances of my march did not allow a more leisurely survey of the geology of a country so well deserving the attention of more competent geologists, or of forming a more regular map of the road described ; but I shall hope that my sketches may help to connect the descriptions of other observers, the present route being, I believe, unexplored.

The formations appear to be distinctly divided into five principal divisions.

The first division includes the traet of country lying between Nagpoor and Baitool to the south bank of the Machna river.

An unvaried formation of trap oecurs during the whole of this distance, and the face of the country is covered with round wacken boulders.

The trap forms the southern and eastern boundaries of the valley, and it stretches away to the SW., but its extent in this direction and to the east I am not acquainted with.

Second Division.—The second division comprises the space within the southern and northern Ghàts on the Machna.

This river at Baitool is running to the west, and, after winding round some hills, it re-crosses the road, running east to join the Towa river at Shahpoor. The distance is about 27 miles, the intermediate country hilly.

On the north bank of the Machna, at Baitool, trap no longer appears ; it is followed by strata of quartz and mica schist, traversing the plain

* Reprinted from the Journal of the Asiatic Society of Bengal, vol. iii. p. 71.—Ed.

up to the hills north of the cantonments. These are of quartz, brittle, very highly stratified, and vertically disposed; the layers seldom exceed 11 inches in thickness. The specimens from this locality are marked A.

Nos. 1, 2, and 3 are loose specimens from the plain; 2 and 3 would be found, I think, to enter into the hills. The superstratum of the hills is a sandy clay marl, which continues nearly the whole way to Neempanee.

No. 4 is a specimen of the only limestone found near Baitool; it rises abruptly about ten feet from the bed of a nulla of calcareous sandstone. The limestone No. 5 occurs lying on the right of the road about five miles north of Baitool, and crosses the road at the bottom of a small ravine.

The puddingstone, No. 6, appears about ten miles from Baitool to the east of the road, elevated above the plain a foot or so only; it is exceedingly hard, broken with great difficulty, and chips off then in thin, flat, conchoidal pieces. After crossing the nulla at Neempanee the trap rock No. 7 rises above a black alluvial soil, and rounded masses of 10 and 11 are scattered about. Further on, the road becomes full of ravines, and the gneiss, 11, is found in mass, but in intimate connection with the unstratified rock, 10. The trap, 10, in many places shows itself superincumbent on 10 and 11. At the top of the Neempanee Ghàt, the granite No. 9 forms nearly the whole summit of the hill, mixed, however, with 10, and the northern descent of the Ghàt is principally composed of this latter. After passing the Ghàt, at the banks of a nulla, is a low hill of granite and greenstone together, 12 and 13. This latter occurred also above the Neempanee Ghàt, shooting up through the soil in roundish masses, and near Baitool, to the NE. of the cantonments; the walls of the fort of Keeslah have been built with the same stone. It is met with occasionally proceeding north, intermixed with quartz, until arriving near to Shahpoor, where common trap reappears, and thence the remainder of the road is over a sandy clay soil.

Third Division.—The third division includes the country between the Machna river and the nulla, one and a half mile south of Keeslah, and is bounded on the W. by the small range of Jamgurh hills, which is a ramification from the Mahadeo hills after they change their direction to the SW.

After passing the Machna at Shahpoor all traces of granite are lost, and the sandstones, B 1 and 2, become very general. The sandstone strata extend, with very little interruption, from Shahpoor to Keeslah and to the foot of the Bhoragurh and Jamgurh hills, frequently showing themselves above the alluvial soil, and traversed occasionally by veins of quartz and trap, as at a nulla half way between Shahpoor and the

Bhora Nuddee, where a trap vein (No. 4), about twelve yards wide, passes through the sandstone from a SE. direction. It forms the bed of the nulla, and can be traced for a considerable distance.

The trap dike is itself intersected in various directions by No. 5 in veins not exceeding 3 feet.

The specimens B, No. 3, were taken from a vertically disposed mass about 10 feet in width, which crosses the road on descending a low hill of sandstone, No. 2. The quartz runs east and west, and is with great difficulty broken across the laminæ.

About four miles from the Machna river, and three miles up the Bhora Nuddee, are the seams of coal, displayed on both banks of the stream under a thick bed of sandstone.* All the small nullas run over sandstone beds. After crossing the Bhora Nuddee, trap again immediately occurs, and continues for a mile and a half to the base of a hill of sandstone. The trap is traversed by a vein of calcareous spar, No. 6, about six inches wide. No trap appears further north; and after crossing the sandstone hills, the road passes over a black alluvial soil, which continues to the river north of Keesla, and the only rock met with is sandstone grit, No. 7.

Fourth Division.—The fourth division comprises the low range of hills between Keeslah and Putroda, forming the pass to the valley of the Nerbudda. These hills form a part of the great range of Mahadeo hills, which at this point form a salient angle projecting to the north-west.

After crossing the nulla north of Keeslah, the road lies over kankars, or tufaceous limestones, for a short distance, until reaching some low hills, where commences a mica schist formation, with and without garnets, and interstratified with whitish and greyish limestones, granular and micaceous. The road is thickly strewed with loose limestones and kankars.

Little mica-slate occurs in the low ground, except passing into, or intimately connected with, micaceous limestone.

Specimens, C 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12, were taken from the immediate vicinity of the road, and their positions are so confused and intricate that I could not attempt to describe the order in which they are arranged. Granular limestone and mica-slate appear to form the main rocks, but the whole are intimately blended together and alternately passing into each other.

No. 2 apparently composes the entire mass of two or three low hills. Nos. 3 and 4 form some undulating land near No. 2; on the east of the road near these rocks are abundant specimens of a greenstone rock, in

* See notice of specimens of the same coal received from Captain Ousclley. Journ. As. Soc. vol. ii. p. 435.

appearance being hornstone crystals imbedded in lime. The garnets in the mica-slates are, as far as I have ascertained, all imperfect, soft, and ochrey coloured.

The limestone specimens, 5 and 7, occur very generally along the west of the road, and 7 forms a hillock by the side of a nulla about 15 feet high, irregular and steep; 6 and 8, specimens of micaceous limestone or of mica schist and limestone passing into each other, are found in the banks and beds of nullas.

10 forms the top of a small hill west of the road near the end of the pass towards Putroda; it appears to repose on a substratum of mica-slate.

The specimens marked D are from the neighbourhood of the Hathee Doab hill and pool.

D 1 is the limestone burnt for use for the works at Hoshungabad.

D 2 is an abundant rock extending E. and W., and up the road to Baitool.

The Nos. 6, 7, 8, 9 form the hill of Hathee-Doab; 6 forms the base, and 8 the summit of the hill.

D 1, 2, and 4.—Compact limestones found on either side of the Hathee-Doab hills; the quartz, 3 and 6, are scattered about on the road to Hathee-Doab; 5 forms the foot of the hills; 9 and 10 are loose specimens met with here and there.

Fifth Division.—The fifth division extends from Putroda to the Nerbudda at Hoshungabad.

After passing through the hills a rich field of cultivation opens to view, and the rocks are lost under the deep alluvial soil of the valley of the Nerbudda. South of the river, two insulated mounds of new red sandstone, rising abruptly from the plain about 1½ mile from cantonments, are the only rocks which show themselves on the side of the river, and they are shoots from the northern or Vindya Range, which, opposite Hoshungabad, are of this formation.

In excavating two wells of the depth of about 70 feet at Hoshungabad, no rock was met with, but the coarse calcareous conglomerate common in the bed of the Nerbudda.*

At the junction of the Towa river with the Nerbudda, four miles above Hoshungabad, sandstone ridges cross the river; and 60 miles below, at Hindia, the river is traversed by a basaltic dike, and the intermediate rapids between those two points are formed of sandstones and coarse conglomerates, rising in some places several feet above the level of the river; opposite the cantonments the bank is formed of the conglomerate, and has all the appearance of the ruins of old uncoursed rubble work, E.

* This is probably the ossiferous conglomerate of the Nerbudda, which is found to accompany it and its tributaries more or less throughout, and of which the ossiferous conglomerate of Perim Island, about to be described, appears to be the marine termination.—Ed.

The specimens N and I B are from the road by Jamanee to Boorda, and from Neelgurh, a hill lying to the east of the road from Jamanee. Nos. 1 and 2, I B, limestones, lie under the trap No. 3, I B; the limestone 4 I B is at the foot of the Ghàt; fine-grained sandstones, 5, 6, I B, cover the ascent, in which trap is again met, with indurated clays and sandstones, as 5; 6 and 10, I B, form the beds of nullas between the Ghàt and the coal strata in the Bhora Nuddee.

Specimens referred to in the above account.

A 1, Granite, large, irregular, of white quartz and silvery mica.
A 2 & 3, Mica schist.
A 4, Foliated tufaceous limestone.
A 5, A reddish brecciated limestone.
A 6, A siliceous conglomerate.
A 7, Compact wacken.
A 9, Large-grained granite, flukes of silver mica, white quartz, and light flesh-coloured felspar.
A 10, A dark-red, small-grained syenitic granite, nearly all felspar.
A 11, Gneiss, dark, small mica in layers.
A 12, Grey granite, dark mica decomposing.
A 13, Much hornblende, white quartz, and perhaps felspar mica, one or two spots.
B 1, Very fine-grained sandstone, with thin veins of quartz and quartz crystals in bunches.
B 4, Brown wacken, containing large crystals of —— ?
B 6, Dark aluminous shale, traversed by very minute veins of calc-spar.
B 3, Vesicular laminated white quartz.
B 2, Minute-grained soft sandstone.
B 6, Pure white calc-spar.
B 7, Hard sandstone grit.
C 1, Mica slate.
C 2, Ditto with garnets, and contorted.
C 3, Ditto, filled with large garnets; the mica in the 3 above, in very minute crystals.
C 4, Hornblende crystals, with specks of mica greenstone.
C 5, White granular limestone.
C 6, Limestone with mica.
C 7, Granular limestone, as 5.
C 8, A dark-brown stone, lime, and mica.
C 9, Mica in lime.
C 10, A hornblende rock.
C 11, Mica schist, passing into lime.
C 12, A conglomerate of mica, schist, and hornblende crystals in lime.
D 1, A tufaceous limestone.
D 2, Crystallised limestone.
D 3, A schistose granular limestone, mica in strata.
D 4, Calc conglomerate.
D 5, Ditto tuff.
D 6, Quartz rock, grey.
D 7, Ditto ditto, resembling a siliceous conglomerate.
D 8, 9, Ditto, ditto.
D 1, Flinty whitish limestone.
D 2, Buff coloured ditto.
D 3, Common white quartz.
D 4, Striped red and white ditto.
D 5, Mica schist with garnets.
D 6, Ditto striped red ditto.
D 7, Ditto, ditto.
D 8, A limestone conglomerate.
D 9, Nodule of greenstone.
D 10, Black clay slate.
E, Conglomerate of the bed of the Nerbudda.
I B 2, 3, and 7, Grits.
Nos. 5½ and 7½, Conglomerates.
No. 5, A white tufaceous limestone, imperfectly crystallised.

[The specimens are deposited in the Museum of the Bengal Asiatic Society.]

Note on Perim Island, in the Gulf of Cambay. By Lieutenant R. Ethersey, I.N.*

[Read November 1838.]

Perim island, situated in the Gulf of Cambay, is in latitude 21° 35′ 19″ N., longitude 72° 34′ 48″ E. It is 1,800 yards long, and from 300 to 500 yards wide, lying NNW. and SSE.; bears from Gogah 39° E., distant four and a half miles, and lies two and a half miles off shore. It is a singular island, surrounded by an extensive rocky-reef, which on all sides, except the south, is steep; eleven and twelve fathoms water, in several parts, being within five and ten yards of the rocks forming the reef.

At low-water spring tides, the channel between it and a rocky reef in the centre is only 1,200 yards wide, and has an extraordinary depth of 360 feet, the bottom yellow clay. Due west of the light there is 240 feet, and to the northward of the deepest part of this channel, which is NNW. of the island, the depths gradually decrease to 180 feet due west of the north end of the reef. On the SE. side of the island there is a depth of 198 feet within three-quarters of a mile of the reef, which decreases towards the north to 160 and 168 feet, rocks, and rocks and sand.

It has been surrounded by a strong stone wall, a part of which is still visible on the western side, and the ruins of it are apparent all round; in that part which stands on the western side there is a doorway, composed of large well-cut stones, and is very similar in appearance to that on the island of Shalbet. There are some ruins immediately inside this doorway, which are nearly buried beneath the loose sand; at the NNW. end there are also some other ruins, but not extensive. Half way between the light and the NNW. end there are the remains of a tank, which, from the side which still stands, appears to have been well built, but of no great extent.

The light-tower stands on a high sandhill, and is composed of solid masonry; is 26 feet high, out of which rises a spar 60 feet, upon which the lanthorn is shipped, the whole being supported by shrouds. The light consists of eight burners, and is 102 feet above high-water mark. Hills of sand line the west side, and both ends of the island; general height from 20 to 40 feet. The SE. side is low and covered with

* Reprinted from the Transactions of the Bombay Geograph. Soc. vol. ii. p. 55.—Ed.

a little vegetable mould mixed with stones, which admits of cultivation, although on a small scale.

Besides the Lascars belonging to the Light establishment, a number of Coolee families reside here during great part of the year; they have a few cattle and goats, which find a scanty subsistence about the low grounds.

The island is composed of tertiary strata; the SSE. end terminates in a cliff which exposes horizontal beds of puddingstone, which are separated by sandy clay; the order of superposition is as follows, commencing from the surface :—

	Ft.	In.
Reddish mould mixed with stony rubbish	3	0
1. Yellow puddingstone	1	6
2. Sandy clay	1	0
3. Dark coloured puddingstone	0	6
4. Sandy clay	4	0
5. Yellow puddingstone	1	0
6. Sandy clay	0	6
7. Recent sandstone	0	6
8. Sandy clay	8	0
9. Yellow puddingstone	1	2

At high spring the tide flows above the last stratum. None of the beds appear to dip, and none preserve an uniform thickness throughout the cliff, and in one part the sandstone disappears altogether. Fig. 3 is a section of an angle of the cliff; the strata in the same order and thickness as above, which were measured at this part; the numbers refer to the specimens which accompany this.* This part appears to be an elevated mound, as no appearance of rock is to be seen on the other side of the sandhills, although they are not more than from 80 to 100 yards wide, which appears more probable from the circumstance of a well having been dug at the foot of the hill, on which the lighthouse stands, at an elevation of eight or ten feet above high-water mark, and no rock was met with until 23 feet had been excavated, through sand and sandy clay, when a stratum of puddingstone was cut through, which was three feet thick, when water immediately flowed. The section (fig. 2) of the SSE. end of the island in a line ENE. and WSW. will give a better idea of my meaning.

On the dry reef which surrounds the island, no regular strata are discernible, the whole being confused heaps of rock mixed with mud, sand, and clay; the rock is chiefly yellow puddingstone (breccia), in which, on the SE. end of the island, most of the fossil remains were found. There is one exception, however, to this, which occurs on the western

* In the Society's Museum.

side of the island, where, at low-water spring tides, I observed a regular horizontal stratum of yellow and a reddish-yellow clay, extending nearly one mile to the southward. In one part this rises into a cliff eight and nine feet high, but in general it only shows itself a foot or two above the water. Nos. 10 and 11 are specimens of the cliff, the face of which is curiously marked by curved lines, and is full of little excavations, apparently the work of some testacea. About 200 yards to the north of this cliff there are several large blocks of rock, of which No. 12 is a specimen; the top of the highest of these is on a level with the top of the cliff, and, as they rest upon yellow clay, it is probable they are not in the position they originally occupied. Fig. 1 is a view of the cliff from the westward. No. 14 is a specimen from a small reef on the opposite side of the channel, the whole of the rock resting on yellow clay, proceeding across to the main. Nos. 4, 13, and 14 are the rocks met with, lying in confused broken masses, mixed with clay, sand, and mud; no regular strata to be seen, and the rock disappears altogether above high-water mark. The coast is lined with sandhills. I examined several small watercourses inland, but could not discover rock.

There are large rocks in twenty-eight and thirty fathoms on the E. and NE. side of the island, but I have never been able to procure a specimen. The upper part of the clay cliff, of which Nos. 10 and 11 are specimens, is 20 feet from the lower part of the stratum of puddingstone, No. 9 of Perim Bluff.

List of Minerals referred to.

1, Conglomerate, composed chiefly of quartz, sand, and pebbles, united by a clay basis.
2, Saliferous soft sandstone.
3, Puddingstone.
4, Breccia.
5, Sandstone (fine grained).
6, Conglomerate, nearly the same in composition as No. 1, with the pebbles of larger size.
7, 8, and 9, not received.
10, Laminated clay.
11, Laminated clay.
12, Not received.
13, Coarse sandstone, or granular quartz rock, highly ferruginous.
14, Conglomerate, composed of broken marine shells and quartz pebbles, imbedded in an argillaceous cement.

Description of some Fossil Remains of Dinotherium, Giraffe, and other Mammalia, from the Gulf of Cambay, Western Coast of India, chiefly from the Collection presented by Captain Fulljames, of the Bombay Engineers, to the Museum of the Geological Society. By H. Falconer, M.D., F.R.S., F.L.S.*

During the late meeting of the British Association at Cambridge, I made a communication† to the Geological section on some new additions to the fossil Fauna of India, from Perim Island in the Gulf of Cambay. Among these were mentioned a species of *Dinotherium*, *Giraffe*, and a new Ruminant genus of a size nearly equalling the *Sivatherium*, found associated with remains of *Mastodon*, *Elephant*, *Rhinoceros*, *Hippopotamus*, and several species of Ruminants. The occurrence of *Dinotherium* in the extinct Fauna of India is a point of such interest that no delay ought to take place in laying before palæontologists the evidence upon which the statement is founded ; and as the Geological Society possesses the largest collection of Perim Island fossils, to which I have had access, including remains of most of the species to be noticed in the sequel, the pages of its journal are the fittest place for this communication, the main object, indeed, of which is to do justice to the meritorious labours of Captain Fulljames of the Bombay Engineers, one of the earliest and most successful explorers of the ossiferous beds of Perim Island. This is the more called for, as considerable delay has occurred in the description and determination of the remains which that officer collected and transmitted to England several years ago.

Perim‡ is a small island, situated in lat. 21° 31′, in the Gulf of Cambay, nearly opposite the estuary of the Nerbudda river and separated about 500 yards from the coast of Kattiwar in Guzerat, by a channel which Captain Fulljames states to be 75 fathoms deep. The island is about three miles in circumference, being from one and a half to two miles in length, and in breadth one-half to three-quarters of a mile. The only particulars regarding its structure, with which I am acquainted, have been given by Captain Fulljames and Dr. Lush.§ The highest point of the land is said to be not more than 60 feet above

* Reprinted from the Quarterly Journal of the Geological Society of London, vol. i. p. 356, 1845.—Ed.

† This communication was read on Tuesday, 24th June.

‡ Captain Fulljames, Journal Asiatic Society of Bengal, vol. v. p. 289.

§ *Loc. citat.* Lush, idem. vol. v. p. 767.

high-water mark. The western side presents cliffs of conglomerate, of about 30 feet above the sea, "the upper strata being of compact sandstone, all perfectly horizontal."* Captain Fulljames describes the order of succession, commencing from the surface, as thus :—

1. Loose sand and gravel.
2. Conglomerate, composed of sandstone, clay, and silex.
3. Yellow and whitish clay, with nodules of sandstone.
4. Conglomerate as above (No. 2).
5. Calcareo-siliceous sandstone, with a few fossils.
6. Conglomerate.
7. Indurated clay, more or less compact.
8. Conglomerate, being the principal ossiferous bed.

No precise measurement is given of these beds, but the deepest strata of conglomerate are described to be about 3 feet thick, although in general, they do not run more than 18 inches to 2 feet, and for the most part are horizontal. "On the western side of the island, however, the strata are much disturbed, being fractured and dipping at an acute angle to the east, on the southern end of the island sandstone appears below the fossil stratum of conglomerate, dipping to the north at an angle of 25°." "Capital fresh water is procurable on the island, rising from 20 feet below the surface ; it is found below the stratum of sandstone."† Dr. Lush states that, "proceeding from the south point towards the eastward, layers of kunkur are met with below the sandstone." He also adds that shells and other fossils are found in the conglomerate, besides the osseous remains. But none of those shells are to be seen in the specimens, to which I have been able to refer, in the Geological Society's collection, or at the British Museum.

Our information regarding the geological structure of both sides of the Gulf of Cambay is at present exceedingly imperfect; but much may be expected when the unpublished researches of the lamented Malcolmson are brought out, as he is known to have carefully determined the succession and age of the tertiary beds along the coast of the Northern Concan. In regard to what is known, Dr. Lush describes the sandstone of Bombay as appearing at Mahim, Seergaum, and Danù in horizontal strata, and "evidently above the trap." At Gundavie, the shell sandstone disappears, and beds of clay and kunkur present themselves in the line of section from Gundavie to Surat. From this point to the Keem river, nothing is seen but the "black cotton soil;" on the right bank of the Keem, sandstone and conglomerate are exposed, according to Dr. Lush, in the following order:—

* Lush, *loc. citat.*

† Fulljames, *loc. citat.*

Section on the right bank of the Keen.

1. Alluvial soil, with masses of conglomerate.. 6 feet.
2. Horizontal beds of sandstone in thin layers.. 3 ,,
3. Sandstone .... 5 ,,
4. Coarse conglomerate (bed of the river).

Respecting the Kattiwar coast, nearest which Perim Island is placed, Dr. Lush mentions the conglomerate as reappearing at Gogah, close to the island where masses of the rock containing shells are dug out of the beach. This conglomerate appeared to him to contain no fragments of trap, although the central ridge of Kattiwar, including the hill of Politana, is composed of trap, which is also seen at Bhownuggur.* Captain Fulljames states that he has found " a similar formation to that of Perim all along the coast from Gogah to Gossnath Point, where a firm sandstone is quarried, and of which the splendid Sráwak temples of Politana are built." Captain Fulljames, in a separate paper,† gives an account of the strata passed through, in an experimental boring at the town of Gogah. Of the 320 feet mentioned in the Section, the uppermost 74 consist of sand and gravel 11 feet, stiff black clay 6 feet, sand and clay 10 feet, soft sandstone alternating with thin seams of different coloured clays, sand and gravel 13 feet, and, lowermost, a very hard siliceous sandstone 9 feet thick. The inferior portion of the section is composed of a great bed of dark clay, which has been penetrated down to 246 feet, containing pyrites and broken shells. The whole of this mass appears to be above the conglomerate, but it is not shown whether the absence of the clay deposit at Perim is owing to denudation, or to its upheaval before the clay on the coast was deposited. Captain Fulljames states that he had discovered fossil remains like those of Perim Island down the coasts towards Gossnath, and in a similar formation.

The first announcement of the Perim fossils is given in a communication, dated 17th April 1836, by Baron Carl von Hügel,‡ in which he mentions their having been discovered by Dr. Lush. Among the remains which he enumerates are, bones of the *Mastodon latidens*, the core of the horn of a species of Bos, the head of a boar, and a rodent. Captain Fulljames concedes the priority of discovery to Dr. Lush, but immediately after followed up the inquiry by more extended researches, commencing in April of the same year; and it is to him that we are indebted for the greater part of the Perim fossils which are to be found in the museum of the Asiatic Societies of Calcutta and Bom-

* Dr Malcolmson, however, (vide *post*, p. 367) mentions the occurrence of trap pebbles in these same tertiary beds.

† Journ. Asiat. Soc. of Beng. vol. vi. p. 787.

‡ Ibid. vol. v. p. 288 (May, 1836).

bay, and of the Geological Society of London. Among those which he first met with he mentions "teeth of *Mammoth*, *Mastodon*, *Palæotherium*, *Hippopotamus*, *Rhinoceros*, and a number of other smaller animals; elephants' tusks; the head of some large saurian animal; tortoise; one half of a deer's foot; and a shell in siliceous sandstone." In the collection which Captain Fulljames sent to the Asiatic Society of Calcutta, Mr. James Prinsep* "enumerates many jaws of the *Mastodon* in fine preservation; also teeth or jaws of the *Hippopotamus*, *Elephant*, *Rhinoceros*, a large animal assimilating thereto (*Lophiodon ?*), *Sus*, *Anthracotherium* (?), *Deer*, *Ox*, many vertebræ and unidentified bones and horns; tortoise fragments, and a peculiarly perfect saurian head."† These identifications are not to be considered, in several of the instances, as more than approximative; for neither of these gentlemen professes to be familiar with the subject of fossil bones.

No further account of these remains has appeared in any of the Indian journals since that time. In 1840, Captain Fulljames sent his donation to the Geological Society, and about the same time some specimens from the same locality were presented by Miss Pepper to the British Museum.

Judging from the matrix which adheres to them, the Perim fossils seem to be imbedded, in most cases, in a calcareo-ferruginous conglomerate, composed of nodules of indurated yellow clay, cemented together by a paste of sand and clay. Some of them are attached to patches of a hard argillaceous sandstone. Many of them have had the matrix washed off by the action of the sea, and are in this case generally covered over with remains of small species of serpula and other recent marine shells. The mineral character of the bones shows that they are penetrated with siliceous infiltration, like a great portion of the Sewalik fossils, and in consequence they present a great degree of hardness. The same character holds in many of the osseous remains from the crag; like the latter, the Perim bones, under the action of the sea, wear down into a polished vitreous surface.

Dinotherium. See Pl. XIV. figs. 1 and 1 *a*.‡

The first of these remains to be noticed is a fragment (figs. 1 and 1*a*) consisting of the posterior half of one of the inferior molars of a species *Dinotherium*. The correspondence of the specimen with the teeth of the large European species is so complete in the form of the gable shaped grinding ridge, its transverse direction, and the reflected marginal bulges into which it swells out on either side, together with the characteristic crenulation of the edge, that there can be no doubt of its

* *Loc. citat.* vol. v. p. 290. † Jour. Asiat. Soc. of Beng. vol. vi. p. 78, January, 1837.

‡ For the Plate, the reader is referred to the Journal from which this article has been reprinted, *loc. cit.*—Ed.

belonging to the genus Dinotherium. The peculiar "talon," or heel ridge, is developed in the same degree and with a like amount of crenulation along its edge. The fragment is represented in section in fig. 1 *a*, the internal structure exhibiting the same agreement with that of the European Dinotherium indicated by the external form. The centre is occupied by a rhomboidal core of arenaceous matrix marking the form of the unossified pulp nucleus. I have compared it minutely with a corresponding section of the same tooth (the penultimate of the lower jaw) of *Dinotherium giganteum* (figs. 2 and 2 *a*) from Eppelsheim; and the only perceptible difference is, that the angle formed by the ridge of the ivory is more acute, and the enamel thicker in the Indian than in the European form. Perhaps no conclusion can be safely drawn from this observed difference of angle in the ivory ridge, as it may be a peculiarity of the individual. The greater thickness of enamel is probably of more importance, and may represent a mark of specific distinction. The specimen, however, is much too defective to warrant any opinion in regard to the relations of the Perim fossil to the European species, except that it was quite as large as the *D. giganteum.* We are fortunately able to determine the position of the tooth in the jaw with some confidence. The upper grinders in Dinotherium have a long low basal ridge in front and behind; while the same teeth in the lower jaw have hardly any ridge in front, and the hind one is considerably more developed than in the upper grinders, so as to form a strongly marked "talon" or heel. The Perim fossil exhibits this heel of large size, while the presence of an impression on the posterior surface proves that there was a tooth behind it. It, therefore, belonged to the penultimate molar of the lower jaw, and apparently to the left side.

In short, there can hardly be a doubt about the specimen belonging to a species of Dinotherium. The only question which can arise is in regard to the correctness of the locality whence the specimen is said to have come. It was presented to the British Museum by the lady whose name is mentioned above, as a Perim Island fossil, along with teeth-specimens of a species of Mastodon known to be found in the Perim deposit. M. König, the eminent conservator of the Palæontological department, who had early recognised the generic relations of the fossil, is confident about the donor and the mentioned locality. An additional confirmation is met with in the mineral condition of the specimen. It exhibits the silicified appearance, which is so prevalent in the Ava, the Sewalik, and Indian fossils generally. The ivory core is fissured into a vast number of radiating minute segments, which have been recemented by a siliceous paste (as has happened to certain agates), and the whole of the structure—enamel and ivory—has become so thoroughly penetrated with siliceous infiltration, that it

resists the knife and takes on the highest degree of vitreous polish in the section, while the external surface of the enamel, from the same cause, presents an opaline appearance. All the Eppelsheim specimens of Dinotherium, which I have had an opportunity of examining, are, on the other hand, unsilicified, softer, and of less specific gravity. In section their ivory cuts under the knife, and yields a dull earthy surface; while the harder enamel takes on but a very imperfect polish. This circumstance strongly confirms the Indian origin of the fossil. It is very possible that the large animal—"assimilating to the rhinoceros (*Lophiodon?*)"—mentioned by Mr. James Prinsep in the quotation above given, may also belong to Dinotherium. This conjecture is thrown out for the guidance of those connected with the Museum at Bombay and that at Calcutta, who have access to the original specimens. What we know at present must serve in a great measure as an index merely to further inquiries. I would suggest in the mean time designating the Perim fossil provisionally, by the specific name of *Dinotherium Indicum*.

The following are the dimensions of the fragment compared with those of the same tooth of the *Dinotherium giganteum* from Eppelsheim.

	Perim Fossil.	Eppelsheim Specimen.
	In.	In.
Length of penultimate molar lower jaw	..	3·75
Width of ditto at the posterior ridge	3·1	2·75
Length in section of the posterior ridge of ivory at base	1·5	1·75
Height of ditto	0·63	0·63
Thickness of the enamel	0·25	0·19

The fossil is represented in the figures of the natural size.

Giraffe (*Camelopardalis*). Pl. XIV. fig. 5.

This figure represents a fragment comprising the posterior half of the second cervical vertebra of a giraffe, a good deal mutilated. It shows the characteristic form of the body of the vertebra in this genus, and the cup-shaped articulating surface for the head of the third cervical vertebra. The upper half is wanting, and the posterior oblique processes are broken off. Along the middle of the body there is a well-marked longitudinal ridge, corresponding exactly in form and development to that mentioned as characterising the third cervical vertebra of the *Camelopardalis Sivalensis*, described in the Proceedings of the Geological Society (vol. iv. p. 242); the same remark applies to the lateral ridges of the body, which are decurrent from the inferior transverse processes terminating at the posterior end of the bone in thick expansious. This part of the vertebra is differently formed in both respects in the existing species. The

same resemblance is further shown by the spinous process, the projecting part of which, as in the Sewalik specimen, is placed lower down on the arch than in the living species. The mutilated condition of the fragment prevents the form of this process from being well ascertained; but the very low position and shape of the most salient part determine the vertebra to have belonged to the second of the neck series. There is enough remaining to indicate that there was a like correspondence with the Sewalik fossil in the curve of the body on its under surface, which is more arched than in existing giraffes. The specimen is so weathered and abraded as to present only few points for measurement; but such as may be taken indicate the closest agreement between the fossils :—

	Perim Island Fossil.	Sewalik Fossil.
	In.	In.
Greatest width at the posterior end of the body between the transverse processes	3·1	3·1
Vertical diameter of articulating cup	2·1	2·
Transverse diameter of ditto	2·1	2·

The Perim fossil, like the Sewalik one, is proved to have belonged to an adult and even aged animal, by the marked relief of the ridges, the depth of the muscular depressions, and especially by the circumstance that the posterior articulating surface is completely synostosized with the body of the bone, which is not the case in young animals. With this united correspondence in form, size, and other particulars, I have little hesitation in referring the Perim Island fossil to the second cervical vertebra of the *Camelopardalis Sivalensis*. This specimen is from the collection sent by Captain Fulljames to the Geological Society.

Bramatherium. Pl. XIV. figs. 3, 3 *a*, 4 *a*, 4.

The next of these remains to be noticed are of great interest, as they appear to indicate a large and peculiar form of Ruminants, nearly equalling the Sivatherium in size, but at the same time essentially different. The remains consist of two fragments of the left side of the upper jaw, including the entire series of the superior grinders. Although, probably of the same species, they are certainly not derived from the same individual. The first fragment (fig. 3) is from the collection sent by Captain Fulljames to the Geological Society. It contains the three false or premolars nearly perfect, together with the broken remains of the first true molar. The surface of the enamel (fig. 3 *a*) shows the rugosely furrowed character, which is found in the Sivatherium; but the whole of the teeth in the fossil are at once dis-

tinguished from those of that genus, by the absence from all of them of the sinuous plaited flexures, which the inner crescent of enamel presents in it; they also want the basal collar or "burr" on the inside, which is seen in those of *Sivatherium*. With these discrepancies, which are of considerable importance in the Ruminantia, from the constancy of such modifications in the different groups of this order, the premolars of the fossil correspond in general form and in the relative proportion of width to length with those of *Sivatherium*. The only other genus of Ruminants, which shows the peculiar rugose enamel furrowing in a marked degree, is the giraffe, which agrees with the Perim fossil in the simple direction, without fold, of the inner crescent of enamel. But in this genus the upper premolars are distinguished from those of all other Ruminants by their great excess of width compared with their length. In this respect, and, further, in being considerably more oblique, both in form and in their relative position in the jaw, these teeth in the Perim fossil differ from those of the giraffe. The dimensions of the fossil contrasted with those of the *Sivatherium giganteum*, and of the skull of an adult male giraffe, in the collection of the College of Surgeons, are as follow:—

	Perim fossil No. 1.	Sivatherium Giganteum.	Male Giraffe.
	In.	In.	In.
Length of the three premolars	4·0	4·5	2·9
Length of the first premolar	1·5	1·75	0·9
Width of the 1st "	1·3	1·63	1·1
Length of the 2nd "	1·4	1·5	1·0
Width of the 2nd "	1·5	1·75	1·1
Length of the 3rd "	1·25	1·75	1·0
Width of the 3rd "	..	1·9	1·2
Length of the first or antepenultimate true molar	1·6	1·6	1·33

The second specimen (figs. 4 and 4 *a*), for an examination of which I am indebted to the kindness of Major Jervis, of the Bombay Engineers, is also from Perim Island, and shows the hindmost premolar, together with the three back or true molars, nearly perfect. Like the premolar of the other specimen, these teeth, besides being smaller, differ from their equivalents in *Sivatherium giganteum*, by the absence of the flexuous direction of the enamel, and of the basal ridge at the inside. In these particulars, and also in the presence of a minute or rudimentary cone of enamel on the inner side at the base, between the barrel divisions of the teeth, but attached only to the posterior lobe, they correspond with the other molars of the giraffe. But the anterior pillar of enamel on the outer surface of the front half of these teeth is considerably thicker in proportion in the fossil than in the giraffe; while the outer surface of the posterior half is more expanded in length, and is more hollow than in the latter genus. A still more important difference is,

that in the fossil there is no tendency to a basal mammilla or enamel lobe at the outside between the barrel divisions of the two backmost molars as in the larger fossil giraffe of India (Geological Proceedings, *antè cit.* Pl. II. figs. 3, 3 *a*, and 4); while the middle of each of these divisions at the inner side is so compressed vertically, as almost to present an obsolete or indistinct form of keel. The following are the comparative dimensions, as in the case of the previous specimen :—

	Perim fossil No. 2.	Sivatherium Giganteum.	Male Giraffe.
	In.	In.	In.
Length of the series of three back molars	4·63	5·0	3·9
Length of the first back molar	1·6	1·63	1·33
Width of the 1st ditto	1.75	2·0	1·97
Length of the 2nd ditto	1·75	2·0	1·37
Width of the 2nd ditto	1·9	2·0	1·37
Length of the 3rd ditto	1·6	2·0	1·37
Width of the 3rd ditto	..	1·75	1·37

It is not necessary to follow up the comparison of the fossil teeth with those of the *Bovidæ*, *Cervidæ*, and other families of the order, from all of which they appear to be more removed than from the *Sivatherium* and *Giraffe*. The molars of the Ruminantia generally are formed so much upon the same plan, that it is not easy to draw sufficient generic distinctions from them alone. The characters presented by these Perim fossils, so far as they go, certainly distinguish them from the *Sivatherium*, and also from the giraffes, fossil and recent, but their nearest affinity appears to be with the latter genus, and they probably belong to the same family. The materials presented here, as in the case of the Dinotherium, are much too scanty at present for any conclusive opinion on the subject. Meanwhile, under the conviction of the generic distinctness of the Perim Ruminant, I propose considering it as a genus under the name of *Bramatherium*,* with the specific title of *B. Perimense* to mark the rich and interesting fossil locality where it was found.

The Dinotherium, Giraffe, and Bramatherium are the only Perim fossils which it is intended to particularise by description in this communication. But Captain Fulljames's collection includes specimens of a great many other forms, which prove that the clay conglomerates of the Gulf of Cambay contain entombed in them the remains of a very extensive and varied fauna. Among them there occurs one species of Mastodon, one of Elephant, a large species of Rhinoceros, Hippopotamus,

* The name *Sivotherium*, derived from the Hindoo god *Siva*, having been admitted for one great fossil Ruminant from India, *Bramatherium*, derived from the god *Bramah*, may conveniently be applied to another; the ordinal relationship of the two will thus be easily remembered, together with their common Indian origin.

Sus, Equus, several species of Antelope, Bos, two species of Crocodile, one of which is of the Gavial type; several forms of fresh-water Tortoises, with fish vertebræ two and a half to three inches in diameter. These will be noticed in detail, in the work upon which Captain Cautley and myself are engaged, on the fossil fauna of the Sewalik hills. The principal point of interest about them, requiring mention on this occasion, is, that the mass of the Perim fossil belongs to the same genera and species which are found in the Sewalik hills, and in the ossiferous beds of the Irawaddi in Ava. We have thus conclusive proof that, in the later tertiary period, as at present, one and the same vertebrate fauna ranged from the banks of the Irawaddi, on the eastern side of the Bay of Bengal, 1,700 miles up along the foot of the Himalayahs to the Indus, where it escapes from these mountains, and thence across the continent to the western side of India. We are now getting the first glimpse of the evidence, regarding the range and distribution of the species. Some, as at present, were common over the whole extent of country, while others appear to have been limited to, or had their force of development in a particular tract. The prevailing species of Mastodon from Perim is identical with one of the forms described by Mr. Clift, under the name of *M. Latidens*, in his excellent memoir in the Geological Transactions, 2nd series, vol. ii. p. 371, this nominal species appearing to include two very distinct forms. One of these (Mr. Clift's, Pl. XXXVII. figs. 1—4) seems to have been common on the western side of India, and in Ava, while it is but rarely found in the Sewalik hills. The Perim *Sus* is identical with a Sewalik species (*Sus Hysudricus* Fal. and Caut.); and a like agreement has been noticed as holding with one species of Giraffe. The Dinotherium and Bramatherium have not yet been observed amidst the fossils of the Sewalik hills, while the gigantic tortoise (*Colossochelys Atlas*) ranged from the Sewalik hills to the Irrawaddi.* The Hexaprotodon form of Hippopotamus occurs in Perim island, Ava, the valley of the Nerbudda river, and the Sewalik hills.

I have had occasion in more than one instance, in joint communications with Captain Cautley to the Geological Society, to refer to the singular richness of the ancient Fauna of India in mammiferous forms. As a general expression of the leading features, it may be stated that it appears to have been composed of representative forms of all ages, from the oldest of the tertiary period down to the modern, and of all the geographical divisions of the old continent grouped together into one comprehensive fauna, in the countries along the valley of the Ganges. The Dinotherium of the miocene period of Europe was, till now, a notable exception, but the fossil described in the preceding pages

* There are fragments of this great Chelonion among the fossils brought by Mr. Crawford from Ava.

shows that Ancient India was not without a representative of this most remarkable genus. In addition to most of the known types of Ruminants, we have now evidence that the same country had, in the Sivatherium and Bramatherium, at least two colossal forms of this order.

In regard to the precise determination of the age of the ossiferous deposits of India, the problem still remains to be solved. The western coast of the peninsula will, in all probability, furnish the most certain and numerous data for its solution ; as we may expect there to find deposits and organic contents corresponding to the numerous alterations of upheavement and submergence which the land on that side of the continent has undergone. Fossil remains of Elephant, Hippopotamus, Equus, &c. were discovered by Dr. Spilsbury* in the valley of the Nerbudda, near Jabalpur, in a bed of limestone capped by a thick mass of basalt, and traces of mammiferous remains have been found in other parts of the basaltic district of Central India. Extensive lacustrine deposits, disrupted and altered by the same igneous rock, have been met with over a wide extent of the Deccan, containing the same species of *Paludina*, *Physa*, *Limnea*, *Unio*, and *Cypris*.†

Reasoning from these facts Dr. Malcolmson was led to the inference "that the part of the Vindhya range near Mandoo was elevated during the same comparatively recent epoch as the Sichel hills, between the Godavery and Taptee, the Gawulgurh range, and the Satpoora mountains south of the Nerbudda." He adds also the following startling generalisation :—Over all these tracts, then, I am justified in believing that at one time extensive lakes and marshy plains existed, full of the ordinary forms of lacustrine life. The precipitous and thirsty mountain ranges which intersect India, and which now rise bare and burnt up in inaccessible cliffs, which for months of every year hardly afford water for the birds of the air, must then have exhibited vast plains, full of fresh-water lakes and marshes, on the muddy shores of which multitudes of gavials, crocodiles, and tortoises must have preyed ; and amidst the rank luxuriance of the bordering vegetation the *Mastodons*, *Hippopotami*, *Bisons*, and *Sivatheria*, must have ranged, whose bones are now found so abundantly scattered over India."‡ Unfortunately, this excellent observer's researches on the Gulf of Cambay have never been published ; but, in a note appended to the paper quoted above, he mentions the occurrence of trap pebbles in the tertiary sandstones of Perim Island and Kattiwar (see *antè*, p. 477), and in the cornelian conglomerates of Rajpeepla and Broach, which are said to be remarkably altered by the intrusion of igneous rocks of a late date.

* Journal Asiatic Society of Bengal, vol. ii. p. 583.

† Malcolmson, Geol. Trans. 2nd series, vol. v. p. 570.

‡ Malcolmson, Journal Bombay Geographical Society, vol. for 1841—44, p. 371.

Supplementary Observations.—Since the preceding remarks were in type, I have had occasion to examine some other Perim Island fossils presented to the British Museum by Miss Pepper, one of which has furnished additional and most unequivocal evidence of a huge Indian species of Dinotherium. The specimen is a superb fragment of the left half of the lower jaw, containing nearly the whole of the adult series of five molars *in situ*. The contour of the body of the jaw is shown in the most perfect state of preservation, the fossil having fortunately been mineralised by means of a very hard silicco-ferruginous infiltration. But it has evidently been long rolled about on the sea-beach as a boulder, so that the crowns of the whole series of molars have been hammered off nearly level with the alveolar margin of the jaw; the surface of the fossil is jet black, and almost all of the matrix has been cleared away, probably by the long-continued action of the sea, which has given it a semi-vitreous polish. That it had latterly been in the sea is distinctly proved by adherent patches of recent marine shells identical with those found on others of the Perim fossils; and the testaceous remains being white, pearly, and fresh-looking, are seen in marked relief upon the black surface of the fossil. The symphysis of the jaw is broken off about two and a half inches in front of the anterior premolar, and the bone is truncated behind exactly opposite the point where the coronoid margin of the ramus begins to rise up, the fracture passing through the middle of the last molar, the anterior ridge of which is visible *in situ* in the jaw.

The dimensions given below will indicate most distinctly the characters by which this fossil differs from the jaw of the *D. giganteum* of Kaup. In relative length, the two agree very closely, the four anterior molars measuring but half an inch more in the Indian than in the European species. But the other proportions are very different. The depth of the jaw measured to the alveolar margin of the second premolar, where the deflection of the symphysis begins alike in both, is 9·2 inches in the former, while it is but 6·9 in the latter, and at the back of the third tooth or first true molar, 8·7 inches to 6·2 inches. The Perim fossil exhibits a like excess of dimensions in relative thickness, the jaw measuring 5·1 inches in diameter under the second premolar, and 6·4 inches at the middle of the penultimate molar, while in the European species the corresponding dimensions are respectively 4 and 5 inches. In consequence of this great depth and thickness, the jaw of the Indian fossil approaches very closely the massive and turgid form seen in the typical Mastodons, such as the *M. giganteus*; while that of the European Dinotherium is comparatively much thinner and more compressed. The inner side of the jaw in the latter is very flat, differing in this respect widely from the Mastodons generally; in the Perim fossil this flatness is much less, not exceeding that of the *Masto-*

don giganteus, and behind the body of the jaw bulges out on either side, so as to yield nearly a circular outline in section, and exactly to represent the form in the American Mastodon. This resemblance is so great, that in the absence of the crowns of the teeth, and from its huge proportions, the fossil when presented to the Museum, and up to this time, has always been regarded as the jaw of a Mastodon. The relationship indicated by the shape of the jaw is further borne out by the form and structure of the penultimate lower tooth, as described in the preceding part of this paper. The enamel, which is thinner in the *D. giganteum*, is as thick in the Indian species as in the lower penultimate of the American Mastodon: the outline of the ivory ridge beneath the enamel is the same in both; the crown ridges have the same transverse, continuous, crenulated, and trenchant form; and, what is most important and significant of all, the hind talon, in respect of form, amount of development, and the characteristic crennlation of its edge, is so precisely similar, that this part in the one exactly represents the corresponding part of the same tooth in the other. The same direction of affinity is further indicated by the nearly horizontal line of protrusion and horizontal plane of wear in the teeth by the form of the ramus, coronoid process, and angle of the jaw, and by the absence of antero-posterior curvature in the outline of its lower surface, in all of which particulars the American Mastodon deviates widely from its congeners, and from the Elephantine type generally, and approximates towards the Dinotherium. This tendency is also shown in the very reduced formula of the teeth-ridges, in the deflection of the symphysis, its thick bluff termination, and in the inferior tusks. I shall soon have occasion in another place to follow up this subject at greater length; and in the mean time must content myself with the simple statement, that the North American Mastodon and the Indian Dinotherium are the nearest connecting forms of the two genera yet known, and that their relationship is far from being remote, perhaps even nearer than that of the American Mastodon to the Indian Elephant or the Mammoth.

The deflection of the symphysis commences immediately behind the second molar, as in the *Din. giganteum*, and it is evidently produced into a great bluff mass, bent downwards as in that species. The section at this point does not include any part of an inferior tusk, or of an alveolus for it; but Dr. Kaup* tells me that the large tusks of the Eppelsheim species, with their alveoli, always terminate considerably in front of the anterior premolar. There is no reason, therefore, to con-

* I have had the advantage, while engaged on the examination of this fossil, to benefit, during his present residence in London, by the intimate knowledge of the structure of the Dinotherium, possessed by this distinguished palæontologist, the founder of the genus. Dr. Kaup was at once convinced of the generic relations of both the fossils, but he is in nowise responsible for any of the opinions here advanced regarding the distinctness of the species, or its affinities.

clude that the Indian had not tusks resembling those of the European species; and although there is no direct evidence to the point, everything in the construction of the symphysis goes to support the presumption that there were tusks. The posterior mentary foramen is of large size and situated at the outside under the anterior premolar, exactly as in the Eppelsheim fossil, but at a greater distance from the alveolar border of the jaw. It is much larger than the foramen seen in the cast of the Eppelsheim lower jaw, but no faith can be put in the dimensions of a foramen measured on a cast.

In regard to the teeth, nothing is seen of their crowns, which have been broken off close to the alveolar margin; but the bony partitions between five teeth are distinctly visible, showing the usual complement in Dinotherium, and proving that the fossil was derived from an adult animal. These five teeth consist of two premolars and three true molars. They diminish in width from the backmost forwards, as in the European species. The anterior premolar has two lobes, the front one being compressed and sharpened off forwards into a cuneiform edge; the rear lobe being shorter and broader. This tooth is upwards of half an inch longer than that belonging to the jaw of the great specimen figured by Kaup. The second premolar is nearly square in outline, but wider behind. It appears to have had two ridges, and four fangs. The third tooth, or first true molar, presents a length of 4 inches by 2·8 of extreme breadth, while that of the Eppelsheim cast measures 3·6 by 2·6. We have in this excess of length conclusive proof that the Indian, like the European species, possessed the remarkable character of having the first true molar three-ridged, and more complex in its form than the two backmost grinders. The crown is so utterly mutilated as to afford no evidence regarding the form of these ridges. The second or penultimate true molar is nearly square in its plane outline, but more than half an inch longer and wider than in the European species. The tooth-specimen described in the body of this paper was inferred to be the penultimate inferior, and it was probably derived from a female or small-sized individual. The remains in the jaw appear to indicate that this tooth was two-ridged, with a talon, as in the European species. Of the third and last molar only the anterior half remains, and we have no direct proof how many ridges it bore; but the number was most probably two, with a talon, as in the European species. The portion which remains presents two distinct and slightly divaricating fangs, indicating, among many others which could be added, another character of resemblance to the North American Mastodon.

The following are the dimensions of the fossil compared with those of a cast of the jaw of the great head specimen, supposed to have been a male, figured and described by Kaup.

	Mastodon giganteus.*	Dinotherium Indicum from Perim Island.	Dinotherium giganteum of Eppelsheim.
	In.	In.	In.
Length of the fragment	..	17·0	..
Ditto of the four anterior teeth	..	13·5	13·0
Ditto of the 1st premolar	..	3·5	2·9
Width of ditto behind	..	2·2	2·2
Length of 2nd ditto	..	2·9	3·3
Width of ditto behind	..	2·6	2·7
Length of 3rd or first true molar tooth	..	4·0	3·6
Width of ditto behind	..	2·8	3·0
Length of 4th tooth (2nd true molar)	..	3·9	3·3
Width of ditto	..	3·5	2·9
Depth of jaw to alveolar margin at the 2nd premolar	7·5	9·2	6·9
Ditto at 3rd tooth (1st true molar)	6·6	8·7	6·2
Width of jaw at 2nd premolar	5·7	5·1	4·0
Ditto at the middle of 4th tooth (or penultimate true molar)	6·5	6·4	5·0
Distance between the upper margin mentary foramen and alveolus of 1st premolar	..	3·6	2·2
Ditto from inferior margin to ditto	..	4·75	3·4

The Dinotherium of Eppelsheim is known to range through a very wide difference of size, dependent on sexual or individual peculiarities, and several nominal species, chiefly founded upon this character, have been described by authors. But Dr. Kaup informs me, that he now admits but two species, *D. giganteum* and *D. Kœnigii*, as he regards all the rest, such as *D. Cuvieri*, *D. Bavaricum*, *D. proavum*, &c. to be merely dwarfed varieties, or females of *D. giganteum*. M. de Blainville has arrived at nearly the same conclusion in his Osteographie. It would be unsafe, therefore, to found any opinion regarding the Indian fossil merely on a difference of size. But, in addition to the larger dimensions, the very remarkable peculiarities in the form of the jaw, indicated by its great depth in front, the excessive width, massive form, and circular outline in section behind, together with the absence of the flattening of the inner side, which is so marked in every specimen of *D. giganteum*, taken in conjunction with the very significant difference in the thickness of the enamel, appear to furnish the strongest evidence that the Indian fossil belongs to a distinct species. It is to be kept in mind also, that all these differential characters tend in a remarkable manner, in the direction of greater affinity with the *Mastodon giganteus*. In corroboration of this view, it deserves to be stated that, of the numerous fossil Proboscidia discovered in India we† have found

* N.B.—The four measurements of Mastodon giganteus, given for comparison, are taken at points of the jaw corresponding to those of the Dinotheria.

† In stating this I use the plural pronoun *we*, intending to intimate that the opinion is one in which my colleague, Captain Cautley, also concurs.

that all the forms are specifically distinct from those which occur in Europe. I have now no hesitation in regarding both the Perim fossils to belong to a distinct species of *Dinotherium*, larger than the *D. giganteum*, and more closely allied to the mastodons, which, as proposed in the preceding pages, may be called *D. Indicum*.

Note.—In the Athenæum No. 923, p. 662, there is an abstract of a paper by Mr. A. Bettington, read to the Royal Asiatic Society, on the 21st of June of this year, giving an account of a finely preserved cranium of a huge Ruminant, found by that gentleman in Perim Island: * I have repeatedly seen the specimen, which was exhibited at the anniversary meeting of the Geological Society on the 17th of February last; but as unpublished material, which I had no authority to quote, I have not felt at liberty to refer to it in the descriptions given in this paper. Mr. Bettington institutes a comparison of his fossil with the Sivatherium and Giraffe, and considers it, so far as the abstract above quoted indicates, to be distinct from both. The circumstance that this cranium and the fossils here described are from the same locality, creates a strong presumption that they may belong to the same genus or even to the same species; but I am unable to say in how far the teeth agree, as I have not had an opportunity for making the necessary comparison. Mr. Bettington, as quoted in the abstract, appears to consider that, in addition to horn buttresses behind the orbits, there was a pair of recurved rear horns in his fossil, at the side of the occiput, placed as in the buffalo. This inference, if well founded, would be against the affinities here attributed to Captain Fulljames's fossil, should it prove to belong to the same species. Among the remains mentioned as having been found associated with this cranium by Mr. Bettington, are species of Mastodon, Rhinoceros, several forms of Ruminants, Crocodiles, &c.

References to the Figures in Plate XIV.

Fig. 1. Dinother. Indicum;—posterior ridge and *talon* of the penultimate lower molar left side, seen from outside: (*a*) the ridge, (*b*) the talon.

Fig. 2ª Ditto in section, showing the enamel ivory and pulp nucleus; (*a*′) ridge; (*b*′) talon.

Figs. 2 and 2ª. The same in Dinoth. giganteum.

Figs. 3 and 3ª. (*a, b, c*) the three premolars of Bramatherium Perimense; (*d*) the ante-penultimate or anterior true molar; (*b*′, 3ª) showing the rugous surface of the enamel.

Figs. 4, 4ª. Plane and erect views of the last premolar (*c, c*′); and the three true molars (*d, d*′; *e, e*′; *f, f*′) of Bramath. Perimense.

Fig. 5. Camelopardalis Sivalensis, second cervical vertebra, side view; (*b*) mesial longitudinal ridge under side of the body; (*e*) alæform expansion of the transverse processes; (*g*) interior oblique process; (*h*) ridge of the spinous process.

* See this paper *in extenso*, with Plate, Journ. Royal As. Soc. vol. viii. p. 340.—Ed.

Account of the Cornelian Mines in the Neighbourhood of Baroach, in a Letter to the Secretary from John Copland, Esq., *of the Bombay Medical Establishment.**

[Read 28th March 1815.]

Having arrived at Baroach with the European part of the expedition, on our route from Bombay to Baroda, to be placed under the command of Colonel Holmes, I took advantage of the few days the troops remained there to visit the famous tree denominated Kubeer Bur, and the cornelian mines in the territories of the Raja of Rajpiplee. I regret that my time was too limited to enable me to give such an account of these objects as I could wish ; but as the latter, as far as my observation goes, has never been publicly noticed, I am induced to hazard this, and shall be gratified if you think my mite worthy to be added to the stock of Eastern knowledge already collected by the Bombay Literary Society.

Accompanied by one or two others actuated by the same curiosity, I left Baroach (the Bargasa of the ancients, Bhreegoo Khsheto of the Hindoos) on the 3rd of December 1814, about five o'clock P. M., and committed myself to the celebrated and sacred stream Rewa, commonly called Nerbudda, at the turn of the tide, but from the great quantity of water discharged by this mighty river we had soon to pull against the stream. About midnight we arrived at the island of Kubeer Bur, twelve miles NE. of Baroach. The moon, while it enabled us to form a tolerably accurate idea of the tree, left darkness enough in its shades greatly to increase the solemn grandeur of the scene. The lofty arches and colonnades, the immense festoons of roots, the extent of ground it covered, and its enormous trunks, proclaimed its great antiquity, and struck me with an awe similar to what is inspired by a fine Gothic cathedral,—while the fresh green of its thick foliage showed it still in the vigour of life ; I should guess it to cover from three to four acres. Its branches rise so high that many miles off it is a conspicuous object, bearing a resemblance to a hill on the extremity of the island. The tree is washed on its eastern base by the river, having to the west and south a ridge of sand, which is covered by the spring tides, and on the north the island extends for three miles, exhibiting a plain most fruitful in whatever requires a light sandy soil. The river here, altering its course from north and south, runs east and west. At the time of the high swells at the latter end of the rains the island is overflowed, and the few inhabitants, like so many of the monkey tribe (with whom they mingle), are compelled to take refuge in the lofty branches of the tree, and remain there

* Reprinted from the Transactions of the Literary Society of Bombay, vol. i. p. 289.—1819.—Ed.

for several days until the water subsides, the current being too rapid for a boat to render them relief. The popular tradition among the Hindoos concerning the tree is, that a man of great sanctity named Kubeer, having cleaned his teeth, as practised in India, with a piece of stick, stuck it into the ground, that it took root and became what it now is. He was afterwards canonized, and his image we saw sitting in a temple near one of the oldest-looking trunks (his metamorphosed tooth-brush). To this temple, people from far and near come to pay their devotions: the ceremonies are performed by the religious mendicants called Byragees, under the superintendence of a head man, who is stationary; the rest (with the exception of the pupils who beg in the neighbouring main-land) being wanderers from all parts of India. We intended to pass the night under the protection of this saint; but our cots not having come up, we were obliged to return to the barge, and sleep in boat-cloaks instead of a temple. At day-break we landed opposite the village of Neemoodra, which is three miles distant from the river, and south of Kubeer Bur, where we found our horses waiting: the mines lie about twelve miles to the eastward of this village. About five miles beyond Neemoodra we came to a rivulet named Kaweeree, and although of no importance during the dry season, it becomes a most formidable river in the rains. Its bed consists chiefly of quartz and agate pebbles; among the latter were many varieties, the most uncommon, I remarked, were of a dark-blue colour with white veins. A stratified rock, varying from 50 to 100 feet in height, overhangs the river on the western side for several miles. I regret much not having had time to examine it particularly; its dip toward the south-east might have been 45°. On ascending from the bed of the river, we passed on our left the little village of Rutunpoor, in which resides a Thanadar on the part of the Rajpiplee State (whose jurisdiction is only in matters of Police, and confined to the district dependent on this village), and proceeded onward by a narrow footpath through jungle, having rising ground almost the whole way to the mines. The country is but here and there cultivated, yielding crops of juwaree and other productions common in Guzerat; but, owing to the stony and unproductive nature of the soil, it vies not with the opposite side of the Nerbudda, which is cultivated like a garden, and in the far greater part of which no stones of any description are to be found. The diversity of scenery,—hills and valleys, pebbly beds of rivers, precipitous rocks, and extensive plains covered with jungle,—was sufficiently romantic. On account of the tigers with which the country abounds, no human habitations were found nearer the mines than Rutunpoor, which is seven miles off. The miners reside at Neemoodra, where alone the stones are burnt. The mines are in the wildest part of the jungle, and are very numerous; they are shafts working perpendi-

cularly downward, about four feet wide; the deepest we saw was 50 feet; some extend in a horizontal direction at the bottom, but, in consequence of the earliness of the season, few had reached a depth sufficient to render this turn necessary, and in those that had it was not carried many feet. In using the term "earliness of season," it is proper to mention that the nature of the pits is such as to prevent their being worked a second year on account of the heavy rains which cause the banks to fall in, so that new ones are opened at the commencement of every fair season. We arrived at the mines about seven o'clock A. M., when none of the workmen had come except one, who accompanied us as a guide from Neemoodra. We were informed that the fire-damp (hydrogen gas) was not uncommon in the mines, and that the miners did not descend till the sun had risen sufficiently to dispel the vapours. We went to the bottom of one pit, about 30 feet deep, without any assistance from ropes or ladders, by means of small niches for the feet and hands on opposite sides of the pit, but understood that the miners always made use of a rope to hold by, of which we could not avail ourselves, as the workmen at the close of their labour carry to their homes the simple instruments of their vocation, together with the stones which the day's labour has acquired. The soil is gravelly, consisting chiefly of quartz sand reddened by iron, and a little clay. The nodules may weigh from a few ounces to two or even three pounds, and lie very close to each other; but for the most part distinct, not in strata but scattered through the mass, and in the greatest abundance. I saw none of a red colour at the mines; some were blackish-olive, like common dark flints, others somewhat lighter, and others lighter still with a slight milky tinge. The first, our guide informed us, would be black when burnt; the second, red; and the third, white. In this he may have been correct; but I doubt the fact as to the first, which we found in a proportion inconsistent with the well-known rarity of a black cornelian; I sent specimens of each to Captain Hall of the Royal Navy, whose zeal in all scientific researches, I doubt not, has settled this point. I confess myself of opinion that there can be no precise rules drawn from the appearance of the stones before, for that which they will assume after burning, because it depends partly on the degree of heat they undergo. A red cornelian by an intense heat will become white; but, as far as my observations go, no stone of the former colour is found so in the mines (excepting jaspers), although a large proportion of them assume it at Neemoodra. Many also, after having been burnt, show both colours, sometimes distinct and sometimes mixed, and of a pinky hue; while the colour was uniform, or very nearly so, in all which I remarked at the mines. The lightest-coloured stones come out of the fire of a much more delicate and transparent white than before, and often sur-

rounded by a cortex of red, but without any distinct line separating the colours. We were unfortunate in the time of visiting Neemoodra, for all the good stones had been removed, and only a few heaps of refuse left. I saw none imbedded in rock, as flints are in chalk; some nodules, on being broken, showed a mixture of quartz and agate, and others, in a crust of quartz minutely crystallized on the inner surface, contained a black oxide of iron of a powdery appearance, many pieces of which we found by themselves in the gravel. Hematites, chiefly of the brown and green (with red spots) varieties, mocha stones, and jaspers of various colours, are very common here; indeed, the last was found in almost every part of the province we visited on our route; each stone is chipped in the mine to discover its quality, and those which are approved separated from the refuse, heaps of which lay at the mouth of every pit which had been worked.

I shall now attempt to give an account of the mode in which the cornelians undergo the action of fire, as derived from the testimony of a respectable native attached to the Adawlut at Baroach, who was formerly in the cornelian trade, and had himself superintended the process at Neemoodra; his account is corroborated by our personal observation, and by what we learned on the spot. The stones are brought to this village every evening, spread on the ground, exposed to the sun to prepare them for the further process, and turned every fifteenth day till the time of burning, which is only once a year, one month before the commencement of the monsoon. They are then put into round earthen pots about fourteen inches in diameter, the bottoms of which having been taken out, and the pots inverted (mouth downward), the pieces taken from the bottoms are put inside, and placed over the mouths to prevent the stones falling out; in this state the pots are placed side by side in a trench of indefinite length, but of which the depth and breadth are about two feet, having a layer of five or six inches of dry goats' dung below, and the same above the pots. This is set on fire about eight o'clock in the evening, all the fuel is consumed before daybreak, when the pots are removed from the trench to the open air for the stones to cool, which requires about three hours; after this they are taken out of the pots, piled into heaps, and again chipped for the same purpose as when taken from the mines, and are finally thrown into a pit, where they remain till called for (more to be out of the way of thieves, than as constituting any part of the operation). From Neemoodra the cornelians are carried to Cambay by the merchants who come from thence, where they are cut and formed into the beautiful and much sought after ornaments peculiar to the place.

I ought to have mentioned that the miners do not forsake a pit on

meeting with a spring, but merely change the direction ; the water never rising to any great height.*

The Rajpiplee country has long been celebrated among the natives who live in its neighbourhood for the variety of its earths and mineral productions; and is certainly a rich field for the mineralogist and geologist. The native above mentioned informed me that, about twenty-five years ago, slight shocks of earthquakes were felt in the province, but that they were far from being frequent occurrences.

On our return from the mines to Neemoodra we took a circuitous route which brought us to a hill of considerable height, which we ascended, and enjoyed a most extensive prospect. It appears to be composed of vitrified rock, and I think there can scarcely be a doubt entertained of its volcanic origin. On the summit stands the tomb (in good repair) of the tutelar saint of the country, Baba Ghor, to whom adoration is paid more as a deity than a saint, under whose particular protection are the cornelian mines, and to whom the miners recommend themselves before descending into the pit. A little below the tomb is a hollow (answering to the crater) containing a tank of water about 100 feet in length and 50 in breadth, well built of hewn stone, having steps on its four sides descending in the most regular manner to the bottom. Viewing these works of human art in a spot now so sequestered, at a distance from all human habitation, the country covered with jungle as far as the eye can reach, giving shelter to wild beasts ever at enmity with man, we cannot but admire the political as well as physical changes that are constantly taking place in the world, while we learn that this desert was once the site of many flourishing towns and villages. At the shrine of this saint the people of the neighbouring countries offer up their prayers on the 12th of the Mahomedan month of Rujub ; thousands then flocking to the sacred spot to perform the vows they have made. This assemblage (in common with other Mahomedan festivals) is denominated a *Mela* (holy fair). To ascertain whether their vows will be accepted, the pilgrims throw twelve cocoanuts into the tank ; if the saint be propitious, thirteen rise to the surface ; but if otherwise, only the number thrown in. Baba Ghor was a prince of the dynasty of Ghuoree, a race which furnished some of the first emperors after the invasion of Hindostan by the Mahomedans. He was sent by his father, the reigning emperor (he himself being heir to the throne), with so large an army, that his personal attendants, says the tradition, amounted to thirty thousand men, for the purpose of prosecuting the war against the infidels (Hindoos). The huge army was completely routed near these hills, and the prince with

* This proves the high situation of the bed, and might lead to some interesting conclusions in geology.

all his attendants fell. The tomb has been erected, no doubt, by the followers of Mahomed, subsequently to regaining their power in this quarter, to perpetuate the name of a martyr to the great cause.

We descended at the opposite side of the hill by a path paved with the fragments of temples despoiled by Mahomedan bigotry, to the extent of nearly a mile; proceeded onwards to Neemoodra, where, having made the inquiries previously related, we returned to the barge, and crossed over to Shookulteruth, where we arrived at twelve or one o'clock, breakfasted, and returned by water to Baroach, where we landed about six P. M.

Camp, near Jeenore, 27th February 1815.

Principal Facts in the other Geological Papers connected with the Western Part of the River Nerbudda. Extracted by the EDITOR.

Geological Notes on the Northern Concan, and a small Portion of Guzerat and Kattywar. By CHARLES LUSH, M.D.

[Bengal As. Soc. Journ. vol. i. p. 763.—1836. 7 pages 8vo.]

The author sets out from Bombay, where he observes "strata of sandstone containing shells," which subsequent remarks prove to be the "shell-concrete," and not the "fresh-water formation" under the basalt. This sandstone formation he traces to Seergaum, and on the road through Tarapur, Dannú, and Jayebúrdí; "the strata all horizontal, and evidently above the trap."

"The trap ceases on the coast between Balsar and Gundavi. The last hills being those of Dungri, a low range near the village so called, scarcely more than 100 feet in height, and composed of porphyritic trap.

"At Gundavie are strata of clay containing kunker, and from this point we take leave of trap, as well as of shell-sandstone. Kunker, and clay of various forms now present themselves in the only sections seen between this place and Surat.

"From Surat through Oolpar to the Kim river, nothing but black cotton-soil; on the right bank of the Kim at Sawal is the following section:—

"1. Alluvial, containing irregularly-imbedded masses of conglomerate—6 feet.

"2. Three feet of horizontal strata of sandstone, from one to two inches in thickness each.

"3. Five feet of sandstone, varying in hardness.

"4. Bed of the river, consisting of coarse conglomerate, coarser than the imbedded masses No. 1.

"There is reason to believe that the same rocks form the Rajpipla range of hills and portions of the peninsula of Kattyawar. The most remarkable part of this formation (of sandstone, &c.) is the cornelian deposit at the celebrated mines near the Nerbudda at Ruttunpoor. These mines were described by Mr. Copland (Transactions Literary Society, Bombay [*et antè*, p. 491]). The general account is correct, but Mr. Copland is in error with respect to the appearance of igneous action upon the hill of Bawa Gorea, which consists of sandstone and conglomerate rocks, but not a trace of trap."

Under Ruttunpoor there is a section on the bank of a nulla, "showing, under a superficial stratum of alluvial, sandstone in five feet thick strata,—25 feet deep, inclined at an angle of about 70°.

"The formation containing the cornelians is a deep bed of red gravel, very like London gravel.

"The mines are sunk to about 30 feet, but on digging to 60 feet neither hard rock nor water is met with. I therefore conclude, that this is a partial deposit entirely above the sandstone conglomerate formation, which is denuded at the surface of the nulla before mentioned, which forms also the Bawa Gorea hill, and, I believe, the general range of the Rajpiplas."

Crossing over to Kattyawar the author states:—

"The next point at which I found conglomerate rock was at Gogo, where masses of rock containing shells are dug out from the beach, the upper portions having been carried away by encroachments of the sea.

"These conglomerates appear to contain fragments of a great variety of mountain rocks, always excepting trap. This circumstance affords suspicion that the trap was thrown up subsequently to the deposit of the conglomerates. I say merely suspicion, as I know of no evidence of upheaving, nor the nature of the strata at the points of junction."

The paper then concludes with a short description of Perim Island.

Account of certain Agate Splinters in the Clay bordering the Nerbudda. By Captain ABBOTT.

[Bengal As. Soc. Journ. vol. xiv. p. 756.—1845. 2 pages 8vo.]

Merely mentions that a basin of black trap rock in the valley of the Nerbudda in Nimaur is "perforated by peaks of granite." Also that agates, which are found in the clay overlying the trap, are hardly ever found entire, but almost always in a fragmentary state.

Granite in the Nerbudda. By Captain ABBOTT.

[Bengal As. Soc. Journ. vol. xiv. p. 821. 1 page 8vo.]

This also only states that in an island of the Nerbudda opposite Mundlaisir is a peak of granite; and that the valley of the Nerbudda being 1,600 feet below the table-summit of the Vindyahs, the trap of Malwa may be considered at least of this thickness.—Notices also the amalgamation of the trap with the granite, and the gradual passages of these two rocks here one into the other.

Notes on Lacustrine Tertiary Fossils from the Vindyah Mountains near Mandoo; and on the Period of the Elevation of that Chain. By J. G. MALCOLMSON.

[Trans. Geograph. Soc. Bombay, vol. vi. p. 368.—February 1844. 8 pages 8vo.]

Chiefly identifies fresh-water fossils in specimens of indurated clay from Gharri, a village near the foot of the Nalcha Ghàt, which leads from Mandoo to the table-land of Malwa (presented to the Bombay Asiatic Society by Lieutenant Blake, Bombay Army), with some described by the author in his paper on the fossils of the eastern portion of the great basaltic district of Western India, p. 13, &c. of this volume.

The fossils identified were:—*Physa Prinsepii*, *Paludina Deccanensis*, and *Limnea Subulata*. Casts of the exterior of *Melania quadrilineata*, and of the interior of *Cypris sub-globosa* and *C. cylindrica*.

"These facts," states the author, "establish the important inference, that the part of the Vindyah range near Mandoo was elevated during the same comparatively recent epoch as the Sichel hills between the Godavery and Taptee, the Gawilghur range, and the Satpoora mountains south of the Nerbudda."

The body of the paper consists of theoretical remarks and inferences on the state of this part of India before and after this elevation, accompanying which is the following foot-note, p. 372:—

"The existence of basaltic dikes through the amygdaloid has been long known; but more decisive proof is derived from the occurrence of a great bed of basaltic breccia, containing fragments of a compact basalt and a very porous amygdaloid, like scoriæ, under the basalt capping the Khandalla Ghàt; and also near the summit of Singhur hill fortress, which is a lofty mountain rising above the long spur which extends from the Ghàts across the Deccan between Poonah and Sattarah. Of the same fact, abundant proof is afforded by the distribution of trap pebbles through the tertiary sandstones of Perim Island and Kattyawar, and in the cornelian conglomerates of Broach and Rajpipla, which last

have been remarkably altered by the intrusion of more recent igneous rocks, which I propose to describe in detail at some future period. In the former instances the eruptions may have followed each other almost immediately, but in the last examples a long period must have elapsed."

Extracts from M. J. Elie de Beaumont's Researches on the revolutions of the surface of the globe are then inserted, and the author concludes with the following paragraph on the formation of the Laterite:—

"This widely distributed formation, referred to in the first of the above extracts, known in India under the name of laterite, I believe to have had its origin in the decomposition (generally *in situ*) of rocks containing minerals abounding in iron, such as sienite, hornblende-schist, and basalt; and its ordinary relations will, therefore, afford no proof of the period of the elevation of the chains on the summits or declivities of which it occurs. On the highest part of the hills at Khandalla, the basalt is seen changed *in situ* into this singular rock."

A Visit, in December 1832, *to the Cornelian Mines situated in the Rajpipla Hills to the eastward of Baroach.* By Lieutenant G. Fulljames, Bombay Army.

[Trans. Geograph. Soc. Bombay, vol. i. p. 75.—Nov. 1838. 4 pages 8vo.]

"The strata through which the shafts (30 to 38 feet deep) are sunk appear to be all nearly alike. The superficial beds consist of gravel; then red and yellow ochre, below which fullers' earth and ochre again; then a thin seam of rock containing a large proportion of iron, below which lies the clay in which the cornelians are imbedded," p. 77.

The rest of the paper chiefly consists of a description of the author's journey from Baroach to Ruttunpoor; that of the mines which are "one and half coss" from Ruttunpoor; and the way in which they are worked.

Recent Discovery of Fossil Bones in the Island of Perim.

[Bengal As. Soc. Journ. vol. i. p. 233. 4 pages 8vo.]

This paper consists of extracts from letters by Baron Hugel and Lieutenant G. Fulljames to the Secretary, of which all that need be remembered will be found in the introduction to Dr. Falconer's paper on some fossils from the Island of Perim, p. 475.

Baron Hugel mentions, that part of a tusk of a Mastodon, which was brought to him among other fossils from Perim, measured "from the centre to the outside of the circle 5¼ inches, which gives 10½ inches in diameter, or 34 in circumference."

Note on the Discovery of Fossil Bones of Mammalia in Kattyawar. By Captain G. Fulljames, Bombay Army.

[Journ. of the As. Soc. of Bombay, vol. i. p. 30.—1841. 4 pages 8vo.]

Assuming that Perim Island was once a continuation of Kattyawar, the author seeks for a continuation of the ossiferous conglomerate there, on the mainland, and observes that similar "fossil remains are not only to be found along the coast as far as Gopna Point, but some distance in the interior also."

They were found at the village of Thulsar, which is five coss south of Gogo; "the strata on the coast at Thulsar are similar to those in which the fossil remains are found on Perim, though perhaps not so compact or hard, but lying horizontal, as at Perim.

"At Chota Gopna Point, which projects some distance into the Gulf of Cambay (from the general form of the coast), the strata are similar in all respects to Perim formations, and here I found the most perfect specimens of fossil remains that I discovered on the coast."

Again, "To the west of Gogo and near some Jain tombs I found other fossil specimens in a similar formation to that of Perim, which was being quarried for building purposes at Gogo."

Section of the Strata passed through in an experimental Boring at the Town of Gogo, on the Guzerat Peninsula, Gulf of Cambay. By Lieutenant G. Fulljames.

[Bengal As. Soc. Journ. vol. vi.]

Section condensed.

	Ft.	In.
Rubble	4	0
Sandstone	45	0
Sandy clay, sand-hands, and clay-beds	66	0
Blue clay, with septaria and lignite	214	2
	329	2
The bore was sunk fifteen feet after this and continued in the same material (blue-clay)	15	0
	344	0

A Description of the Island of Perim, with a few Remarks on its Geological formation. By Dr. Nicholson, Bombay Army.

[Journal Bombay As. Soc. vol. i. p. 13. 7 pages 8vo.]

To reprint this paper, with the *Secretary's* compilation which precedes it, would only be to repeat what will be found in Captain Ethersey's and Dr. Falconer's Description of Perim Island, pp. 472, 475, respectively.

Notes on the Geological Structure of Parts of Sinde. By Captain N. Vicary, of the Honorable East India Company's Service. *In a Letter addressed to Sir R. I. Murchison, G.C.St.S., F.G.S., F.R.S., and communicated by him to the Geological Society.**

The following Geological notes were written during an excursion from Kurrachee to Sukkur in November and part of December 1845, and as so little is known with respect to the Geology of Sinde, I trust that even these rude notes may not prove unacceptable.

The station of Kurrachee, latitude 24° 53′, longitude 67° 17′, is situated upon a coarse-grained, dirty yellowish, arenaceous rock, held together by a calcareous cement. In some places this rock is loose-grained and easily worked, in others hard, and containing sufficient calcareous matter to afford an impure lime. In all places it contains fossils in abundance. This rock, although conformable, lies higher in the series, and is more recent than that which composes the elevated parts of the Hala range of mountains. It is in many places directly overlaid by a calcareously cemented conglomerate, in other places a sandstone of some thickness intervenes. This sandstone is usually destitute of fossils, but near Kurrachee some of its thin beds, varying from one inch to two or three feet in thickness are composed almost exclusively of fossil shells.

The pebbles forming the conglomerate are all rounded, and for the most part derived from the nummulitic limestone of the Hala range, and I found some broken remains of oysters and Cerithia in the rock. A conglomerate, retaining the same character, is found flanking the eastern face of the Hala range, from Cape Monze to the west of Mittun-Kot. In some places it attains sufficient elevation to constitute a distinct and well-defined range, and is often of vast thickness. We are still in want of information as to its extent in a northerly direction along the base of the Sulleemaun range.

The neighbourhood of Kurrachee is characterised by low hills, not exceeding 200 feet in height. In many places they appear like islands in a shallow sea, and a subsidence of 150 feet would make them so; in other places they form a continuous narrow range for two or three miles. They are often capped with the conglomerate, disintegrated at the surface, but still cemented beneath. The low intervening valleys and plains are composed of the same coarse arenaceous rock on which

* Reprinted from the Quarterly Journ. of the Geol. Soc. of London, vol. iii. p. 334.—Ed.

Kurrachee stands. It is evident that the conglomerate, sandstones, &c. have there been removed by the action of water, by tidal action, perhaps, while the whole country was submerged. About three miles east of the station there is a low range of hills running nearly parallel with the sea-coast, from which they are now distant between four and five miles. The roek is a fine-grained sandstone without fossils, in some places capped with conglomerate, in other plaees that rock has been swept away. The western face of this sandstone forms an abrupt cliff, and undoubtedly has at some period been subjected to the ebb and flow of the sea. The cliff is everywhere eroded by the action of the waves, and is in many places pierced by saxieavous molluses. About a mile to the southward of these hills, and three miles to the SE. of Kurrachee, the coarse arenaceo-calcareous rock is elevated into low hills, which present a very remarkable appearance. The surfaee is divided into numerous parallel-sided, cistern-like figures by septa of a harder calcareous rock, which has better resisted the action of the elements. The septa are of various thickness, six inches to a foot in height, and include areas of two or three square yards. At this place I found Astrea abundant, a shield-shaped Clypeaster, a very large speeies of Conus (ten inches to a foot in length), a large Strombus, and a buceiniform Volute, upwards of 14 inehes in length and not unlike the "sunk" of the Brahmins. All these specimens were too heavy for a travelling geologist's collection. In the valley, at the base of this hill, there are two springs of intensely salt water.

The following table will serve to give a general idea of the relative position of the beds composing the Hala range, and the formations existing in Sinde :—

1. Conglomerate.
2. Clays and sandstone.
3. Upper bone-bed.
4. Sandstone fossils rare.
5. Lower bone-bed.
6. Coarse arenaceo-calcareous roek, with *Cytherea exoleta ?* and *exarata ;* Spatangi ; no Nummulites.
7. Pale arenaceous limestone, with Hypponyces, Nummulites, and Charoideæ.
8. Nummulitic limestone of the Hala range.
9. Black slates, thickness unknown.

The bone-beds are of a deep rust colour, often soft, but in many places hard, and appearing as if vitrified. In such places there are no fossils, the roek is arenaceous, owing its colour to iron, and seems to be partly cemented by it. The upper bone-bed is often absent, as in the vicinity

of Kurrachee. I have seen a few bones in the lower part of the sandstone No. 4. The bone-bed No. 5 is found throughout the Hala range from Cape Monze to the Beloochistan hills NE. of the Bolan Pass ; and how much further it may be produced in a northerly direction remains to be determined. This bone-bed is of variable thickness (from 50 to 500 feet), but preserves the abovementioned character everywhere, and is easily recognised even at a distance.

No. 6. The rock of the vicinity of Kurrachee is easily recognised by the abundance of a fossil which I take to be *Cytherea exoleta*, and the absence of nummulites. The next in descending order, No. 7, is not often seen as a distinct bed. It is distinguished by the number and size of individuals belonging to the genus Hypponyx, which it contains, and also by vast numbers of a small circular-shaped fossil.

No. 8 constitutes the backbone of the Hala* range, and abounds with nummulites, &c. I shall make an attempt hereafter to point out such fossils as are peculiar to each bed, and, in the absence of any designation, I shall refer to each bed by the numbers given above.

The harbour of Kurrachee is protected by two rocky islets and Minora Point, all of the same formation. A section on the seaward face of Minora Point exhibited the following details in a descending order: Conglomerate, 60 feet ; sandstone, 3 feet ; bed composed almost exclusively of Ostreæ, 2 to 4 feet ; sandstone, 5 feet, at base becoming highly calcareous, and there containing innumerable Turritellæ ; lastly, a fine-grained sandstone extending to the base of the cliff, in which no fossils were apparent.

Minora Point is connected with the Hala range about twenty-five miles distant, in the direction of Cape Monze, by a narrow bank of dry sand, which alone separates the present harbour from the open sea. On the eastern side of the harbour there is also a dry bar of sand, stretching from Clifton towards Minora Point. Within the harbour there are mud flats† covered by water at each tide, abounding with three species of Cerithium, one of which I recognised as being also common at the mouth of the Ganges. In the deep water *Placuna placenta* is most abundant, and has been fished for from time immemorial, on account of the pearls often found in the shells. An island close by is covered to the depth of four or five feet, and to an extent of two acres or more, with shells accumulated in this way.

At present no river discharges itself into the harbour, the channels affording little water unless during falls of rain, which I was told take place about once in four years ; but there is every reason to think that a

* The southern portion of the Hala range is styled "Hala or Hurbooe Mountains" in Walker's Map (Brahooick of Pottinger).

† The flats are generally covered with a species of mangrove, *Ægiceras fragrans*.

branch of the Indus at one time discharged itself here. The general shape of the harbour, with its bars and mud flats, is favourable to this idea. About half a mile to the westward of Minora Point, in the direction of Cape Monze, the action of the sea and wind on the beach has laid bare a stratum of black clay containing vast numbers of oysters and broken Cerithia belonging to the species now living in the harbour. At first I was inclined to consider that this was a post-pliocene formation, but I remarked that an inshore wind, or sea breeze as it is called, prevails for a great portion of the year, and blows at times with considerable violence. This wind is constantly drifting the dry sand into the harbour and filling it up, the discharge of water every tide, no doubt, again carrying out a portion of the sand thus drifted. The sea, however, is gradually gaining on the harbour, and will continue to gain on it by the gradual drifting forward of the sand belt, and I have no doubt that the stratum of black clay, with Ostreæ above noticed, was at one time *within* the harbour and formed a portion of its flats. On the land side the harbour is also gradually filling up from the quantity of detritus carried into it by every fall of rain, which remains wherever it is left by the temporary flood. There is *now* no river affording a constant supply of water to carry forward such a deposit, and it is effected only by tidal action, which is not sufficient to keep the harbour open. The sea opposite the mouths of the Indus is, as is well known, shallow, and it is also shallow opposite Kurrachee. At Clifton, on the eastern side of the harbour, at low-water mark, I found the broken stems of trees with roots in their natural position. The grain of the wood was still perceptible, but Pholades had pierced it in all directions, and were still domiciled in it.

About a mile and a half east of the station there is a post-pliocene clay about 60 to 100 yards in breadth, 6 to 10 feet in depth, and a mile in length, which fills a depression, or denudation, in the arenaceous rock, No. 6. It has been cut through by a water-course, and in the section exposed I found numerous Pupæ, Planorbi, Melaniæ, a Terrebellum, numerous broken columellæ of Cerithia, and some beads made of fish-bone, in all respects similar to those worn by native children at the present day. Close to this, on the surface, I found some fossil bones of crocodiles, but in a rolled and broken state.

From Kurrachee, in the direction of Munga-Peer, to the foot of the lower hills (the outskirts of the Hala range), a distance of about four miles, for the most part a dead level, but rising gently near the base of the hills. It is possible that the ancient branch of the Indus, above alluded to, found its way to the harbour in this direction. Sections exposed by digging wells in the plain give the following descending succession :—(*a*) 8 to 10 feet of a stiff yellow clay,

containing numbers of Planorbi, Pupæ, Melaniæ,* with fragments of a small species of Cypræa, and occasionally of oysters and Cerithia ; (*b*) a bed of pebbles evidently derived from the broken-up conglomerate ; (*c*) sand resting on a light blue laminated clay. Approaching the hills the plain becomes gradually obscured by a bed of gravel and large pebbles, increasing in depth to the base of the range on which it rests. From the base of the hills to Munga-Peer, I followed the course of a valley ; the rock composing the elevations on either side being the nummulitic limestone of the Hala range, with its peculiar fossils. Munga-Peer is a basin enclosed by hills, exeepting to the north-west and the valley by which I entered from the SE. There are two hot springs situated near the centre of the basin ; both rise from partings of the strata, whieh at these points crop out at an angle of 50°. The springs are about half a mile apart, and the water is sweet. That of the most northern is so warm (124° Fahr.), that I was obliged to withdraw my hand immediately. The other is 99°.

There is not a vestige of a volcanic rock near, but the nummulitic limestone through which the springs burst has been rendered somewhat erystalline by heat, and the fossils in the rock are almost obliterated. The basin of Munga-Peer is partly filled with a post-plioeene formation, similar in all respects to that noticed above. In addition to the shells above mentioned, I found an Area and a Nerita. The Cerithium is exactly the same as that now existing in the harbour of Kurraehee. I found this clay formation mounting up to a pass through the hills to the westward, at an elevation of 300 feet above the level of the basin. To the NE. this clay contains a great quantity of " Konkur," the well-known tufaceous formation of India. A little further, in the same direetion, there is a narrow cleft in the range of hills separating Munga-Peer from the plain without, through which the drainage of the basin is effected by a small stream, on whose banks I found considerable quantities of a pure white salt, in some plaees six inches in depth ; but as my specimens are lost, I cannot describe it.† From Munga-Peer, I proeeeded in a north-westerly direction to the Hubb river ; after the first mile the land gradually slopes into the valley of the river, in the bed of which I found numerous rolled fragments of

* This Melania is found reeent throughout Sinde, and I have often seen them in water too salt to drink.

† A shallow pond reeeives the water of one of the hot springs, and in it upwards of 300 eroeodiles are domesticated. They have been there from a very remote period, and it seems diffieult to say when they were first plaeed there. They breed, and the young ones are even more numerous than the old. Many of them are quite tame, allowing themselves to be touehed and patted with the hand. The speeies is well known in India under the name of " Mugger." (*Obs. by Dr. Falconer.*—" The Mugger eroeodile of India is perfeetly distinet from the Nile speeies. There are even three Indian speeies of true eroeodile.")

the black slate upon which the nummulitic limestone is known to rest. This being the boundary of our possessions in Sinde, and finding that the formation differed in no respect from that already visited near Deyra in Northern Sinde, I returned to Kurrachee.

From hence, owing to the difficulty of procuring both water and supplies, I was necessitated to proceed in a north-easterly direction towards Hyderabad, instead of moving along the foot of the highest range of the Hala, as I wished. This direction had its advantages, however, as it led me across all the water-courses descending from the Hala range to the Indus.

Leaving the abovementioned salt-springs on my left, and clearing the rock formations of Kurrachee, I came upon an extensive plain composed of a tenacious yellow clay, similar to that seen at Munga-Peer, and, like it, abounding with Pupæ and Melaniæ. The clay is in many places concealed beneath hills of loose drifted sand: two and a half miles beyond Jemadar-ka-lande, and about fifteen and a half miles from Kurrachee, I came upon low sandstone hills with still lower hillocks of various-coloured clay on their northern aspect. I found here scattered on the surface large quantities of the fistular fossil which I have noted under the name of Tubularia, pieces of silicified wood, a tuberculate Pleurotoma, and a small fossil bone. No water being procurable here, I pushed on to Guggul, twenty-five miles in an easterly direction from Kurrachee, and thirteen miles from Jemadar-ka-lande. At about the seventh mile from Jemadar-ka-lande, I came upon a calcareously cemented sandstone with numerous Tubulariæ and Ostreæ. Thence to Guggul there is a plane of tenacious yellow clay, similar to that between Kurrachee and Jemadar-ka-lande, but with gravel beds occasionally coming to the surface. The sections exposed by the Guggul show that the clay at that place rests on a fine stone conglomerate. In the clay immediately above the conglomerate, I found Melaniæ and Pupæ abundant.

Hence to Nao-nehal, on the right bank of the Maulmaree river* (now dry), eleven miles. The country from Guggul to within a quarter of a mile of the Maulmaree rises gradually, and at that place terminates in a sharp escarpment with a general N. and S. direction. (Section 1, Pl. XXII.)

The clays and conglomerate gradually thin off and cease at about the sixth mile from Guggul, and are replaced at the surface by an arenaceo-calcareous rock agreeing closely with No. 6. The descent from the cliff is effected by the Rund Pass, and the elevation above the Maulmaree river may be about 450 to 500 feet. Near the pass there

* All the river-beds are dry at this season from Kurrachee to Kotree near Hyderabad, but water is found by digging to a greater or less depth in the river-beds.

are many scattered islet-like plateaux of small elevation, and appearing as if they had been subjected to the action of water; their overhanging margins were in some places bored by saxicavous molluscs. An examination of the cliff (although its base was usually obscured by *débris*) showed that the lower beds become still more arenaceous, until they assume the form of a fine-grained, pale yellow sandstone; beneath this there is a variegated (red, white, and blue) laminated clay, apparently devoid of fossils. In the *débris* at the base of the cliff I found some fossil bones, evidently disengaged from the arenaceous rock above, as they differ greatly from the fossil bones usually found in Sinde, which for the most part owe their hardness to hydrate of iron. The bones found here are soft and with a calcareous infiltration. Many of them appear to have lain at the bottom of the sea previous to fossilisation, have been rolled by the action of currents, and are occasionally pierced by boring molluscs. The fossil most abundant in the lower part of this rock is an Ostrea, with the upper valve flat and smooth, the lower concave and costate, and evidently a gregarious species. A very large Pecten also occurs, upon which I shall make some remarks hereafter. Nummulites are very rare, but Clypeastra and Spatangi most abundant. Hence I followed the course of the river-bed in a northerly direction along the base of the "Bubbera Steppe" for about seven miles. In the sands and gravel of the river I found innumerable detached nummulites, which are often carried forward even to the Indus, and are doubtless brought down from the Hala range. The Maulmaree, during rain, becomes an impetuous and impassable torrent.

The fossils of the Bubbera Steppe are almost obliterated, apparently by the former action of heat. At the time when the steppe was uplifted a portion of rock about 200 yards in length was left in a mural and almost perpendicular position, and is now about 60 yards from the general line of the Bubbera Steppe. The intervening space is characterised by calcined clays and broken masses of a vitrified arenaceous rock.

In examining the hills to the eastward of the Maulmaree, I found a pale yellow arenaceous limestone with nummulites (No. 7) lying immediately beneath the coarse non-nummulitic rock of Kurrachee (No. 6). In the depressions and water-courses I found comminuted and broken fossil bones in vast abundance, but no entire specimen. From this to Kawranee is fifteen and a half miles in a north-easterly direction; at about the fifth mile I emerged by a pass into a tolerably level country, small hummocks of a pale yellow limestone with Hypponyces occasionally protruding from the general level. The surrounding country is composed of the yellow clay above mentioned, with Melaniæ, Pupæ, &c., but in many places concealed beneath sandhills.

In the Kawranee river-bed, now dry, a good section of the pale

yellow limestone (No. 7) is exposed. In this stratum I observed an Hypponyx and two species of Nummulites to be most abundant, with large quantities of a minute fossil, which was well-known to our army in Caubul under the name of "Petrified Rice,"* claws of Crustacea, a Nautilus, a large Cytherea? and many other fossils.

I proceeded hence to Rodh, thirteen miles over an extensive plain. In some places water-courses had cut down to the rock beneath, which I found to be identical with that of Kawranee (No. 7).

Sections exposed by the Rodh river exhibit conglomerate, cemented towards the base, but disintegrated above, and in many places surmounted by yellow clay of inconsiderable thickness, containing Melaniæ and Pupæ, but no other fossils.

Hence to Woor, eighteen and a half miles in a north-easterly direction. For the first mile conglomerate occasionally protruded through the clay, and then a sandstone nearly horizontal, with pebbles and fossil wood scattered on its surface, the general aspect of the country up to the ninth mile being level. At this point I came upon the pale yellow limestone (No. 7), and hence, by a gentle ascent for about three miles to the Junnett Pass, where I found fossils in all respects agreeing with those obtained at Kawranee.

The country between Kurrachee and Kotree is characterised by a succession of steppes; the slopes at a small angle to the west coincide with the stratification, and the abrupt cliffs have an easterly exposure, at the bases of which water-courses are usually found.

To the NNE. of Junnett Pass, one and a half mile, there is an outline forming seven peaks, known to the natives by the name of Saut-Raee. These peaks have an elevation of from 300 to 400 feet above the plain, and are for the most part composed of the yellow limestone (No. 7). I was unable to visit them, as the only water obtainable at this season in that neighbourhood was putrid and unfit to drink; in fact no water was to be had between Rodh and Woor, eighteen and a half miles. From Junnett Pass, by a gradual descent to Woor, where the country is a level plain, the section exposed by the Woor river is nowhere deep, but shows that the yellow clay of the plain rests on conglomerate. In the river-bed I found numerous nummulites in the sand and gravel; both banks are flanked to a great distance by hills of drift sands, generally crowned with Tamarisk and *Acacia Catechu*. From this to Kotree, twelve miles of level country, being made up of an irregular coating of sand resting on the same yellow clay so often alluded to. Kotree is on the right bank of the Indus opposite to Hyderabad.

* This fossil was since taken to Paris by Sir Roderick Murchison, and was identified by M. A. d'Orbigny to be an Alveolina. The associated forms of this class are in the limestones of Sinde Nummulina and Assilina (D'Orb.).

Having taken in supplies, I proceeded hence to Ukka-Nag, a spring of sweet water in the hills, about seventeen miles NNW. from Kotree; thirteen miles of this was over the plain through which the Indus now finds its way to the sea. I then came upon hills of small elevation trending NNE. and SSW. The range here is composed of isolated hills not exceeding 400 feet above the plain of the Indus, their apices level with nearly horizontal strata, their sides abrupt and precipitous, the uppermost beds being in all respects similar to the non-nummulitic rock (No. 6). The valleys or intervening spaces between these hills have been much disturbed. A variegated clay, abounding with gypsum, is of common occurrence, but contains no fossils. A brown rust-coloured rock is abundantly distributed on the surface near this, in the form of large rounded boulders, and the Kotree blacksmiths occasionally visiting this place select the most promising specimens, and transport them to Kotree for the manufacture of iron.

Hence, in a northerly direction, I proceeded to Buchera in the plain of the Indus, for about fifteen miles, and the country passed through held the same character to within half a mile of the base of the hills; here I found the conglomerate resting on a thin bed of arenaceous rock, which I could not identify, and which reposed upon No. 7. The conglomerate eventually disappeared beneath the yellow clay of the plain.

Water was not to be had within the hills at this season of the year; I was therefore obliged to continue my journey as far as Luckee through the plain of the Indus. The Kotree range of hills terminates nearly west of Majinda, and is succeeded by another range trending nearly north as far as Sehwan; the water of this range, except at Rennie-kote, is salt and unfit for use; the hills attain considerable elevation (from 600 to 800 feet) above the Indus, towards which their aspect is very precipitous; they are the abode of the true Ibex. Between this range and the Indus there are numerous low hillocks of aluminiferous clay, from which the Sindees manufacture alum. I was unable to ascertain the exact relation of these clays with respect to the beds entering into the formation of the more elevated range. The proper time to explore this place would be after a fall of rain, when water would be obtainable from ponds. Moved on to Luckee, which is about sixteen miles to the southward of Sehwan. The range here approaches the river, and is of easy access. It is not so high here as further to the southward, and becomes gradually lower in a northerly direction towards Sehwan, where it terminates. The following section will give some idea of the range of mountain at the Luckee Hot Springs. (Section 2, Pl. XXII.)

I obtained the above section from a transverse cleft dividing the range like many others in the neighbourhood; and from the base of one of

them a hot spring issues, the water of which is highly saline. The curvature of the beds composing the range of hill on the western side of the valley is indeed very interesting, and would at once arrest the attention of the most unobservant person. The bed of the stream (for the most part dry) has a mean breadth of about ten yards. I followed it in a southerly direction for about four miles with the same mural precipices on either side of me; the mural beds to the eastward have evidently been thrown over at the time of upheaval, and were once an overlying portion of the formation to the west. The outer or more eastern face (that next the Indus) is a heap of ruins or *débris*, composed of angular blocks of the same rock, of all sizes, and from the base of this, for two miles, towards the Indus, there is a "boulder gravel," derived from the disintegrated conglomerate. The upper beds of this range are similar to the Kurrachee rock No. 6, and in the clefts are seen to rest on No. 7. The fossils in the rock in the vicinity of the hot springs are almost obliterated, a circumstance previously remarked near the hot springs of Munga-Peer. I entered the valley by a narrow cleft in the eastern barrier opposite to the village of Luckee; the stream of the valley finds egress at the same point. Opposite to the pass, and on the western side of the valley, there is another hot spring, the water of which is highly mineral, and contains sulphur combined with calcareous matter and some salt; it is of the colour of soap-ley and also detergent. A dense scum is constantly rising to the surface of the pond over the spring; some Sindees, who appear to be constantly in attendance here, skim it off, and, when a sufficient quantity is collected, take it away for the purpose of obtaining the sulphur which it contains. They were averse to answering my questions, and would give me no information as to the quantity obtained in the process. I noticed that a quantity of air is extricated from the spring, and is constantly rising in bubbles to the surface. The whole valley smells strongly of sulphuretted hydrogen, which to some persons is very oppressive, causing violent headache. Near the spring, in a perpendicular face of rock beyond my reach, a hole about three inches in diameter was pointed out by my guide; some years since an inflammable gas issued from this, and, having become ignited, was known and revered by the Sindees under the name of "Puri-ka-Chiragh," or the Peris Lamp. It became extinguished some time ago (as the Sindees say) because some impure idolator had bathed in the well.

The water which runs from this spring has great reputation amongst the natives of this country as a remedy in cutaneous diseases. I noticed that it encrusts leaves, branches, &c. with a calcareous coating, and I found some of the species of Melania, so common in Sinde, living in the stream. This is worthy of notice, because the water is so strongly

impregnated with saline matter that it is not drinkable. From hence to near Sehwan the character of the range is the same; at about the fourth mile the Indus washes its base, and the cliff next the river is in ruins, composed of angular blocks of all sizes. Near this place, in the bed No. 7, I found tolerably perfect specimens of a species of Crab, and large but broken specimens of Hypponyx, some portions of which were one inch and a half in thickness. Further on I crossed the range, which, as I before stated, loses its elevation and eventually disappears near Sehwan. To the west there is a broad valley, with numerous low isolated hills of sandstone, and various-coloured clays, but I regret not having had time to examine this place with attention.

From Sehwan I moved across an alluvial plain to Treenee, a quarter of a mile south of the Munchal Lake, and about fourteen miles west of Sehwan. The Munchal Lake at this season was about twenty miles in length (east and west), ten miles in breadth, and is in many places of great depth. I have no doubt that it was excavated in former times by the Indus; the southern side of the lake is for the most part flanked by low hills, which turned the course of the old stream sharply from a southerly direction to east, or perhaps the northward of east, to pass the range of hills terminating near Sehwan. The back-water caused by such a sharp deflection of the current I suppose to have excavated the lake; during the season that the Indus rises it still continues to receive a supply of water, but the current is insignificant. The low hills near Treenee are composed of indurated clays passing downwards into an arenaceous rock, and occasionally capped with boulders derived from the conglomerate. Hence, for fourteen miles round to the western margin of the lake, my road lay for the most part through the low hillocks above mentioned. Alum is obtained by digging in this formation somewhere near to this place (Shah-Hussan), but the Sindee guides took care that I should not see where they procured it. Hence, NNW. to Gaza-Peer, seven miles; up to about the fifth mile I was passing through these low hills, and on approaching the Hala range the beds are seen to be capped with conglomerate and eventually to sink down, the conglomerate only appearing at the surface. The latter rock in a short time also disappears beneath the surface of a level plain two miles in breadth, being the distance to Gaza Peer. These small hills belong to No. 2 of the Table, page 502, and are similar to those mentioned as flanking the Sehwan range near Majindah; they also correspond with those near Ooch, north of Shikarpoor; the beds dip to the east at various angles from 20° to 35°. Gypsum is occasionally found in the clays; I made most diligent search, but was unable to detect a single fossil form. The yellow clay filling the valley is perfectly level, and abounds with

Viviparæ, Pupæ, and Melaniæ. I could not obtain a section anywhere, but have reason to think that the whole rests on the conglomerate.

The above rough section* from Shah-Hussan to the crest of the Hala range, about sixteen miles (though not very correct), will, I hope, be sufficient to give a general idea of the beds forming the Hala mountains; the western beds, marked as vitrified sandstone, strongly resemble the bone-beds, but bones at this point are exceedingly rare, and I found but a few small broken pieces of them.

The conglomerate rises from beneath the clays of the valley at Gaza-Peer, attaining an elevation of from 100 to 250 feet, and forming a well-marked range, stretching north and south as far as I could see; it exhibits an arrangement into distinct beds, dipping to the east at angles varying from 30° to 45°, the cement being calcareous, and the stones mostly of nummulitic limestone. I found a few minute portions of quartz and some Ostreæ (broken) imbedded in it. Moving west, across a narrow valley, I came upon a range equal in height to the conglomerate at Gaza-Peer, with the same direction and general dip; it forms a mural barrier, passable only by those occasional transverse or east and west clefts, so common throughout the Hala mountains; the rock is of a rust colour, the weathered surface of the beds often polished and having the appearance of vitrified sandstone. Next (moving west) came upon the Kurrachee rock No. 6, with its usual fossils; this also forms mural cliffs. Further west there were mural barriers, composed of a hard sonorous rock devoid of fossils, and also appearing like vitrified sandstone; they form two or three parallel, wall-like ranges, and in some places attain an elevation of 400 feet from their base. I found a few detached and broken morsels of bone here, but no other fossils. Passing through these natural walls, I came upon a recent tufaceous formation of great extent, reaching to the base of the highest range of the Hala mountains, about two miles. At first it was much broken and intermingled with fragments of the neighbouring rocks, and from the quantity of detached masses dispersed on the surface, even to Gaza-Peer, I imagine that in former times it must have covered a very wide area. Shortly afterwards I reached the tufa *in situ*, nearly horizontal, containing casts of leaves, branches, &c., numerous Pupæ and Melaniæ. It is to be remarked, that the place thus noted is one and a half mile from the waterfall of Peeth, a point where this tufaceous rock is daily forming. Peeth is at the foot of the central and highest range of the Hala mountains, and, when seen from half a mile distant, it presents an extraordinary and interesting spectacle.†

* Pl. XXII. fig. 3.—1, Shah-Hussan; 2, Indurated clays; 3, Aluminous, gypsum rare; 4, Conglomerate; 5, Alluvial? valley, Gaza-Peer; 6, Vitrified sandstone; 7, Kurrachee rock No. 6.

† Pl. XXII. fig. 4.—1, Arenaceous limestones with nummulites, fossils indistinct; † Hot spring; 2, Nummulitic limestone No. 8.

A valley opens out on the confined plain at the foot of the hills; the mouth of the valley, about 500 yards across, seems as if a wall, not unlike the glacis of a fort, had been built from side to side; a waterfall precipitates itself from above at this distance like a silver thread, the scanty green grass on either side helping to throw it into relief. Close by there are a few scattered trees of *Tecoma undulata*, which aid in softening the monotony of a scene otherwise naked and barren. On reaching the foot of this natural glacis, where I encamped, I found that the rock was entirely composed of recent tufa deposited from the stream of water now flowing. Its height is better than 300 feet, and in some places is of great thickness. The only section I could obtain (near the southern margin) gave a depth of from 25 to 30 feet. It appears stratified (if I may use the term), owing to its deposition in successive layers; the dip on the glacis is from 35° to 45°, accommodating itself to the dip of the nummulitic limestone beneath. The lower and older beds are yellow, the upper and newer white. I found numerous shells imbedded in it, all agreeing with the species at present existing in the neighbourhood. On the face of the glacis there are five elevated tufaceous walls at irregular distances; each wall varies from a foot or less to five feet in height, with the sides in some places nearly perpendicular; three of these are prolonged with a height of five feet for some distance into the plain below; all are channeled above; four of them are old and deserted beds of the stream; the fifth is the course of the present stream, which is not larger than an English mill-stream. The water is derived from a hot spring, and is warm at the head of the waterfall, but becomes cool and parts with much calcareous matter in its descent. The deposit is more rapid on the margins of the stream than in its bed, and hence the walls originate. They occasionally break down from floods or other accidental causes, when the stream spreads over the glacis, giving a fresh coat of deposit over a considerable area; in time the stream again contracts, forming its lateral barriers, and eventually, when limited in its channel, becomes elevated in the manner I have attempted to describe. There are several wide fissures in the tufa, formed doubtless at the time of earthquakes; most of them have been filled up with broken tufa and some foreign substances cemented by a new calcareous infiltration. From the head of the waterfall to the hot spring is about 650 yards. The tufa extends to the spring, but thins off gradually, and here rests on the upturned edges of the limestone beneath. The hot spring rises at the foot of one of the numerous transverse clefts which everywhere intersect the Hala mountains. The water smells of sulphuretted hydrogen, but has little other mineral flavour, tasting like boiled water, and has a pale green colour. Gaseous bubbles are disengaged from the head of the spring

along with the abundant discharge of water. I have endeavoured to give some idea of this place, because a recent fresh-water formation of considerable extent exists, the causes of which are now in operation. In the valleys north and south of this place (Peeth) there are also other tufaceous formations, often of great extent, but the streams or springs from which the deposit was formed have long ceased to exist, and the tufa is broken and dilapidated. From the hot spring I ascended the crest of the Hala range, which at this place has an elevation of about 1,500 feet above the sea; the rock is the nummulitic limestone, so often alluded to as constituting the backbone of these mountains. The beds dip at about 30° to the east, the limestone is hard, compact, and subcrystalline, and the fossils at this point are very imperfect and ill-preserved. The range, characterised by isolated peaks, becomes gradually elevated towards the north, and in that direction was enveloped in clouds at the time I ascended. A continuous ridge, only broken by narrow clefts (formed, I presume, at the time of upheavement), conveys to the mind the best idea of them. The highest portion of the Hala range is not more than 3,500 feet above the sea. I was unable to prosecute my examination further in this direction, owing to the utter deficiency of water in the mountains, and I therefore returned to Peeth. Hence I proceeded northerly six miles to a well two miles beyond Shahdad-ka-gote. The well, the water of which is tepid, is about 70 feet in depth, and is bored through the conglomerate, which is met with at about 12 feet from the surface. From this I proceeded to Ali-Morad-ka-gote, about four and a half miles north-east. The country passed over is sandy and tolerably level, being a plain of from one to two miles in breadth, widening towards the north, and situated between the outer range of mural cliffs and the more elevated Hala mountains. The low hillocks near this are composed of various coloured clays, like those at Shah-Hussan, passing downwards into sandstone, and often crowned with conglomerate, the pebbles of which are small. The beds here, owing to some local disturbance, dip at an angle of about 12° to the west. Hence to Johee, fourteen miles; no water was to be had at any intermediate point, the roads for the most part passing over a naked and barren desert. At this place the villagers informed me that a small river came through the Hala range by the "Kaphooee" Pass, and was to be found in a north-westerly direction from Thulvee. I accordingly pushed on for the latter place, about twenty miles, and thence north-west across the tail of the desert, and by Gool Mahommed-ka-gote, about eighteen miles, to the gorge whence the "Gauj" river debouches on the plain. This river is not laid down in any map that I have seen. At this dry season it was knee-deep and about fifteen yards in breadth, but at certain seasons it is subject to great floods. It rises to the west-

ward of the Hala range, and finds its way by a transverse cleft, known as the Kaphooee Pass, to the plains of Sinde. This place is well calculated for a canal head, and is worthy the attention of the authorities in Sinde. Irrigation is now effected to some distance, but, under European superintendence, much more could be done, and a vast tract of country, now a desert, could be rendered fertile by the judicious use of the water of the Gauj.

The outer range at this place is composed of conglomerate in well-marked beds, dipping into the plain (towards the east) at from 25° to 45°; beneath this there are clay beds and sandstones, with which the conglomerate often alternates. This range, holding the same character, extends north and south of the Gauj river as far as my eye could reach; in some places it attains an elevation of from 600 to 800 feet above the plain. From its base to six, and in some places eight miles, the broken-up conglomerate has been spread out, and exhibits all the characters of an ancient beach. (Section 5, Pl. XXII.)

The valley of the Gauj at first is narrow, being little more than sixty yards in breadth; further on it widens to near a mile, and again contracts, thus forming a basin; this place was overgrown with Tamarisk and Acacia trees, in which I found wild pigs most abundant. The section at page 512, taken from Gaza Peer to the crest of the Hala range, sufficiently explains the relative position of the beds at this place, excepting the local modern tufa, which is not found here.

Following the course of the Gauj, I passed through the conglomerate ranges, and at 3½ miles came upon a cliff with a western escarpment, about 400 feet in height, and based on the Kurrachee non-nummulitic rock (No. 6). This is on the left bank of the river. I found here fossil bones in vast abundance; the bones (as usual, much broken) were at this point chiefly those of the Crocodile. I have remarked that the bone-beds (wherever the fossils abound) are of a deep rubiginous tint. The fossils also partake of the same colour, and as they strongly resemble the bones procured in such abundance at Nahn, I am not without a hope that they will establish a connection between the conglomerate and sandstone (Sewalik) formations flanking the base of the Himalaya and the conglomerate sandstones and bone-beds of Sinde. The cliff above noted is crowned with sandstone, about 150 feet in thickness; beneath this there is a bone-bed of the usual colour, about 60 feet in thickness; next, descending, comes a sandstone bed about the same thickness, and containing some bones; then a bed of clays of various colours, penetrated with veins of gypsum about 80 feet in thickness; then the lower bone-beds of the usual rusty colour; beneath this, marly clays containing Turritella, and a small bivalve in vast numbers; broken pieces of Placuna were also abundant. From this I crossed to

the right bank of the Gauj, and came upon the same formation, which is prolonged in a southerly direction as far as I could see. The cliff is not so high here as on the northern side of the river (to the course of which it stands at a right angle). It is mural towards the west, and I ascended it with much difficulty. The lowest visible rock here is sandstone, upon which a bed of the rust-coloured rock rests, dipping at from 35° to 40° to the east, and showing a strong contrast in colour to the sandstone beneath. In it I found bones most abundant, and at this place I procured some of my best specimens. Many of them were still in their original position imbedded in the rock, the denuded surface of which was here perfectly smooth. At this place I found a jaw-bone lying flat, appearing entire, and as if it had pressed its own depth into the rock at a time when it was soft. Upon attempting to remove it I found that it was loose, and perceived that the bone had been broken into several transverse portions resting in juxtaposition in the original mould, where doubtless the bone had been fossilised previous to the disturbance which upraised the formation. Near this jaw-bone, but on the surface, I found a portion of a remarkable tusk about five inches in length; I am unable to refer it to any described animal, and strongly suspect that it originally belonged to the abovementioned jaw-bone. This tusk, which I believe belonged to the left ramus of the lower jaw (?), has a diameter of about an inch (I write from memory), is slightly curved and pointed, the lower portion cylindric, the outer side of the apex trenchant and sharp-edged, with the inner side rounded. The bones found here, though much broken, have not suffered from attrition, the fractures being for the most part acute. Night came upon me while engaged on this spot, and with much difficulty I retraced my steps to my tent.

All my provisions were now expended, and nothing, not even milk, being obtainable from the Beloochees of this neighbourhood, I was compelled to return to the plain of Sinde. I intended taking in supplies and again returning to this interesting locality, but, on reaching Rajah Derah, about six miles from the outer range, and the nearest village where supplies were to be had, I was informed that an army was in the act of assembling at Roree with the intention of moving on the Punjaub. I, therefore, abandoned my geological excursion, and lost no time in rejoining my regiment at Roree.

From Raja Derah I passed through a belt of low Acacia jungle, re-crossed the tail of the desert, and regained the road from Schwan to Sukkur at a place called Gaza Peer (not to be confounded with "Peer Gaza" above noticed), and thence to Meher, in all about thirty-five miles. The latter place is near the borders of the desert; and the next march, sixteen and a half miles in a northerly direction, lies for the most part

over the desert, the soil of which abounds with saline matter, crackling as if ice-bound under foot. I remarked several places where saltpetre had been manufactured, but none appeared to have been worked lately. In places where saline matter was less prevalent I found on the surface innumerable individuals of the genera Vivipara, Planorbis, Melania, and Lymnea.* From this to Sukkur nothing but plains of sand and alluvium.

In recapitulation I may state, that during this excursion I examined the Hala range of mountains from Cape Monze (lat. 24° 50′) as far north as a point nearly west of Larkhana (lat. 27° 30′), a distance of about 200 miles, my operations being chiefly confined to the eastern aspect of the range. I found the formation uniform, exhibiting everywhere the same tertiary (or infero-tertiary) character.

During February and March 1845, I had an opportunity of seeing, and forwarded a report upon, the mountains of Beloochistan, in which Deyrah and Kahun of the maps is situated. These mountains are east of Dadur and the Bolan Pass, and belong to the same formation, agreeing thus far with the Hala range, as above noticed ; but the valleys and ranges near Deyrah have nearly an east and west direction ; this direction alters towards the north, until these mountains pass into the Sulleeman range. I gained some little information with respect to the latter from a kind of clay which is sent in considerable quantities into Hindoostan as a colouring substance for walls, &c.; it is well known in India under the name of "Mooltaunce Muttee" ; in this I found fossils agreeing closely with those of some beds in the Hala range ; I strongly suspect, therefore, that the formations of Sinde are continued along the base of the Sulleeman mountains up to the base of the Himalayas.

Though perhaps out of place, I am anxious to add a few words with respect to my observations at Subathoo during the last rains. Close to the European barracks I found some large masses of rock, which had been removed for the purpose of forming level ground to build upon. In some of them I noticed fossil bones, and I had one large mass, weighing four cwt., conveyed to my house ; but the stone is intensely hard, and all my efforts to disengage an entire specimen have failed. On inquiry, the Hillmen pointed out several other localities where fossil bones were found, viz. in the Hurreepoor valley between Subathoo and Simla, and a part of the valley separating Subathoo from Kussowlee. I hope to be able to visit these places after my return to Subathoo. In the mean time the existence of fossil bones at Subathoo

* The sandy ground flanking the desert is overgrown by a species of Tamarix, to the branches of which a white translucent manna adhered in great quantities. Three of my servants collected four pounds and a half in an hour, and I remarked that they ate nearly as much as they collected. The Tamarix bore neither flowers nor fruit at the season I saw it (January), so I am doubtful as to the exact species.

is certain. Some thin beds of a very hard blue limestone abounding with fossil shells pass directly through the station. Further down the hill there are beds of a pale-yellow slaty rock in a fissured and decomposing state, in which I found nummulites abundant, and the casts of one species of mollusc. My observations at Subathoo were limited, as I only remained a few months, and that during the rainy season. All my Sinde specimens are at Subathoo, and I am consequently unable to give any account of them at present, but hope to do so shortly after the return of my regiment to that station.

I trust that my slender geological knowledge will be a sufficient apology for all errors in the above Notes. The little I know has been learned in this country, and for the most part in the field of nature. If these rough Notes add ever so little to the geological history of our globe, I shall be delighted, and seek no better reward.

Jullunder, 10*th February* 1847.

Introduction to a Second Memoir of Captain Vicary on the Geology of Parts of Sinde. By Sir R. I. Murchison, G.C.St.S., F.G.S., F.R.S.*

[Read 28th April 1847.]

Geologists are indebted to the enterprising and lamented Burnes for the first general sketch of the structure of the region watered by the Indus. In subsequent years we were furnished with more detailed information by Captain Grant, who, collecting fossils in the Runn of Cutch, gave us the means of ascertaining that, in addition to the nummulitic and conglomerate rocks partially described by Burnes, other portions of that tract were of Jurassic or Oolitic age (Oxford clay, &c.).

When the brilliant victories gained by Sir Charles Napier added Sinde to the British possessions, that officer resolved to ascertain more precisely the geological structure and real mineral condition of the new province. Having driven back the Belooches into their mountains, he directed Captain Vicary, whom he selected for the purpose, to prepare a report on the geological relations of these tracts, which, with the exception of the partial and rapid journeys of Pottinger, Grant, and Christie, were unknown to Europeans. The report of Captain Vicary, on the previously unexplored Muree country from Shahpoor to the Deyrah valley,† was accompanied by a case of fossils collected under circumstances of unusual difficulty.

* Reprinted from the Quart. Journ. of the Geol. Soc. of London, vol. iii. part 1, p. 331.—Ed.

† Shahpoor is in lat. 28° 42′, long. 68° 40′, and the Deyrah valley in lat. 29° 3′, long. 69° 45′.

Having had the honour of being entrusted by the Earl of Ellenborough and Sir Charles Napier with that report of Captain Vicary and with his fossils, I laid them before this Society, and an account of them is printed in the second volume of our Quarterly Journal, p. 260.

I have recently been favoured with another letter from Sir Charles Napier, who, previous to the late occupation of the Punjaub, desired Captain Vicary to gain all possible information respecting the country near Kurrachee at the westernmost debouchure of the Indus, and also to explore the region along the eastern edges of the Hala mountains, and between that range and the Indus.

This object was to a great extent attained (*i. e.* for a distance of about 200 miles from S. to N., viz. from Cape Monze to the hills west of Larkhana*), when the war of the Punjaub compelled Captain Vicary to rejoin his regiment and proceed with it to the station of Subathoo, situated on one of the southernmost spurs of the Himalaya mountains. By this circumstance geologists were sure to profit; for we now learn that, long and rapid as were his marches, Captain Vicary never lost sight of the rocks and their fossils. The collections of the latter are, it is true, still deposited in the distant military quarter of Subathoo, whence we may expect to receive them after some delay. In the mean time it appears to me to be highly desirable that the memoir of Captain Vicary and his sections should be made known to the Geological Society, since it is certain that the Hala mountains, which are essentially composed of nummulitic limestones, are surmounted by tertiary shelly conglomerates, and beds charged with bones of quadrupeds, many of which are of the same character as those described from the Sub-Himalaya or Sewalik Range by our able associates, Dr. Falconer and Major Cautley.

In short we are now in possession of important additional materials to enable us clearly to define the western limits of that grand former coast-line first laid down by Dr. Falconer† along which terrestrial animals lived in the tertiary period; and after comparing the discoveries of Captain Vicary with other admirable data of Major Cautley and Dr. Falconer, we can now unhesitatingly say that the animals of their Sewalik types, which onee lived on the northern shore of the great tertiary depression of Hindoostan, were also inhabitants of its western shores, or the north and south ridges of nummulitic limestone, sandstone, &c. (based on older and Jurassic rocks) which actually form the western limits of British rule or influence in the east.

From what I can gather from foreign Geologists and Palæontologists, particularly from Von Buch, E. de Beaumont, and A. d'Orbigny, it

* Cape Monze is in lat. 24° 50′, and Larkhana in 27° 30′.

† See Transactions of the Royal Asiatic Society.

would appear that they consider these nummulite limestones of Hindoostan to be the exact equivalents of the great "terrain à nummulites" of the Continent of Europe, which ranges from the Mediterranean into Egypt. M. Von Buch had, indeed, the kindness to delineate in a small map (in a note addressed to me last year) the whole range of these rocks from Europe across Egypt and Persia to Hindoostan. This "terrain à nummulites," whether connected, as by some geologists, with the uppermost cretaceous strata, or considered, as by others, to be of true tertiary age, is admitted by continental writers to lie between the "calcaire grossier" above and the white chalk beneath it. To what exact extent, however, some species of nummulites may descend into unequivocal cretaceous rocks loaded with secondary fossils, does not seem to be yet finally settled; for although M. d'Orbigny contends that no true *Nummulina* has been found in strata containing such cretaceous fossils, several other authors have asserted the contrary,* and Professor Edward Forbes is even of opinion that in the Mediterranean (Ægean) such *Nummulinæ* occur in limestones beneath the scaglia or representative of the chalk.

To return, however, to the memoir I now communicate, I am conscious that much has been already done by others in ascertaining the general range of the nummulitic beds from Sinde to the northern portions of the Sulleeman range, and along the base of the Himalaya chain,† on which subject, as well as on the nummulitic salt region, references may be made to Falconer, Jaquemont, Lord, Hutton, Griffiths, Jameson, &c.

On the present occasion, however, I am bound also to call special attention to the efforts made by Captain Vicary to describe in detail the increment of the diurnal tidal accumulations near Kurrachee; to his patient exploration of the eastern edges of the Hala mountains, and his transverse sections of the same; to his curious observations on the linear outbursts in those tracts of hot springs in conjunction with cross fractures of the ridges; to the extraordinary accumulations of travertine, and above all to his copious collections of fossil vertebrata from the extensive tracts of the Hala mountains, along which he has traced bonebeds similar to those of the Sewalik hills. I have therefore written these introductory lines concerning an absent explorer, in the persuasion that his zealous endeavours and the enlightened support of my former brother officer, Sir Charles Napier, will be duly appreciated by Geologists.

* See Sections and Descriptions of the Northern Flanks of the Eastern Alps by Professor Sedgewick and Sir Roderick Murchison, Trans. Geological Society, 2nd ser. vol. iii. p. 301, and the Terrain Hétrurien of Professor Pilla, Trans. Geol. Soc France, vol. ii. p. 163.

† I learn from Dr. Falconer that, about eighteen months ago, Lieutenant Blagrave, employed as a surveyor in Sinde, sent home a large collection of pleistocene, eocene, and nummulitic fossils.

Geological Report on a Portion of the Beloochistan Hills. By Captain N. Vicary. *Communicated by Sir R. I. Murchison, G.C.S., F.G.S.**

[Read 11th March 1846.]

The hill country visited extends from Shahpoor on the western side to Goojcroo on the east, a distance of about ninety miles, and from the sandstone range, bordering the Desert, to the Murray Hills, in a northerly direction, about fifty miles. The strike and the direction of the ranges and of the valleys is nearly east and west, and the mean dip of the beds southerly.

There are seven parallel ranges of mountains gradually increasing in height from the low sandstone range bordering the Desert to the Murray Hills, the most northern point visited. The low sandstone range bordering the Desert was scarcely touched upon, but, from its appearance, I conclude that it does not differ in structure from the second sandstone range; it dies away towards the west, but appeared to extend in an easterly direction as far as the eye could reach.

The second sandstone range in which the Jullock, Gundava, and other passes are situated, extends also to an unknown distance in an easterly direction, but towards the west, near Shahpoor, it approaches, and eventually abuts upon the first limestone range.

I annex a section running nearly north and south, that is, at right angles to the direction of the mountain ranges, and along the pitch of the strata. It is drawn up from memory, and, though not exactly correct, is sufficiently near the truth.†

Between the place called Ooch and Shahpoor, low sandstone hills make their appearance, belonging to the outer range. The dip of the strata is different on different hills, but the mean inclination is south (that is, towards the Desert) at about 12°. A diluvial gravel is spread over the whole, the boulders varying from the size of a man's head to the smallest pebble; these boulders are present on the highest parts of the sandstone ranges, and are derived from the nummulitic limestone to the northward; they contain the same fossils, and have the same mineral structure. Ooch is a remarkable place, and deserves a special notice; it is a point upon which I should be disposed to think volcanic

* Reprinted from the Quart. Journal of the Geol. Soc. of London, vol. ii. p. 260.—Ed.

† Pl. XXII. fig. 6.—*Section from the Murray Hills to the Desert.*—No. 7, Conglomerate of Deyrah Valley; 6, Sandstones and clays; 5, Bone gravel; 4, Conglomerate; 3, Sandstone of second range; 2, Sandstone of first range; 1, Nummulitic limestone.

force may have formerly acted. It is a valley about half a mile in breadth, and two and a half miles in length, and its direction is curved, at first tending towards the east, but soon turning north-east and NNE. The sandstone dips from the valley on each side at an angle of about 15°, presenting an abrupt face inwards of about 200 feet in height. The surface of the rock is strewed with nummulitic limestone, which consists of gravel, with a few small quartz pebbles intermixed; and the sandstone is partially capped with a more recent gravelly sandstone of from two to four feet in thickness, containing numerous nummulites and a few rolled mollusca. Beneath the sandstone, there is an aluminous clay, and the whole is penetrated with veins of foliated gypsum, some of which are of considerable thickness, but neither the sandstone nor aluminous clay affords fossils. The central portion of the valley is highly saline, as are most of the springs, the saline matter (chiefly soda?) effloresces, and could be collected in any quantity. I was told that a tepid spring existed in the centre of the valley, but I was unable to discover it.

From Ooch to the Jullock Pass, in an easterly direction, forty miles, there is little change in the geological aspect of the country,—the same sandstone beneath, and the surface covered with the same diluvial gravel. The only difference to be noted in the Jullock Pass (the second sandstone range) is, that the sandstone is thrown up to a greater elevation. It is identical with the Ooch sandstone, and is capped with similar nummulitic boulders, while the base is the same fine-grained sandstone as that just mentioned without fossils.* The elevation of the highest points above the pass is not more than 400 feet, but these elevations form a well-marked range parallel to the limestone ranges on the north, and also parallel to the lower sandstone range flanking the Desert. The direction of the range is nearly east and west, and the dip tolerably regular to about 15° south, or a little to the east of south. There are numerous passes through this range; they are clefts formed at the time the sandstone was upheaved, and the drainage of the mountains to the north is effected through them.

About six miles from the Jullock Pass, in a north-easterly direction, we enter the Mun Valley. We here find, first, low hills of sandstone crowned with considerable quantities of rust-coloured rounded stones, which have apparently been subjected to heat. In some of these hills I remarked that the pebbles formed a distinct bed, again capped with sandstone. They contain an inconsiderable quantity of iron, and have much the appearance of having been ejected from a volcano. They are often fissured, or hollow, or containing red and yellow ochre, and occasionally sulphur, and even sand. There are no distinct volcanic rocks in the neighbourhood, but I noticed to the westward some small conical

* I had no instrument for ascertaining heights.

hills which I was unable to visit. We next meet with a low range of hillocks distinctly stratified, dipping at about 6° south, composed of a cemented dark-coloured gravel, with considerable quantities of fossil bones imbedded ; the bones exist in great numbers, and some were so large and heavy that I found it impossible to carry them away. Proceeding across the valley in a northerly direction, sandstone hills crowned with the same rust-coloured round stones are again found, and it is to be remarked that the nummulitic boulders are also spread over these hills. Proceeding about a mile further north, we come upon a thin seam of boulder conglomerate, resting on nummulitic limestone ; the boulders are evidently rolled and water-worn portions of the nummulitic limestone beneath. I observed this conglomerate in many other places of considerable thickness, and I have reason to think that all the boulders and gravel overlying the sandstone hills and outer valleys were derived hence. At Trukkee, this conglomerate attains a considerable thickness, amounting to several hundred feet ; in other places it is replaced by the sandstone resting directly on the limestone.

Next in descending order comes the nummulitic limestone *in situ ;* its usual colour is a very dark blue, in some places changing to a grey, and in others, as at Doza Khooshtee, a pale yellow, and is then arenaceous. In some localities where a deep section was exposed I remarked that the limestone became slaty in its structure, and contained fewer of the nummulites, and sometimes none. In this lower portion there are fine specimens of a species of *Cancer ;* I have been as yet unable to refer it to any described species. The dark blue variety of limestone is intensely hard and sonorous, and has apparently been exposed to considerable heat, by which the calcareous matter of the shells has been volatilized, leaving nothing but casts. This limestone is of great thickness, and is the rock which constitutes all the higher ranges of mountains in this part of Beloochistan.

There are four parallel ranges of mountains formed by this limestone, running nearly east and west; the most northern of which visited, viz. the "Murray range," is the highest, and, I imagine, reaches an elevation of about 3,500 feet above the sea. The rock is easily identified, whenever it occurs, by the vast number of nummulites it contains, and by its other fossils ; the low rocky hills upon which Roree and Sukker are situated are an outcrop of the same limestone, containing similar fossils, and in colour resembling the pale arenaceous limestone of Doza Khooshtee. At the upheaving of the limestone, a number of deep clefts seem to have been formed, mostly running north and south, or transverse with respect to the mountain ranges; many of these do not exceed ten feet in breadth,* but equal in depth the mountains in which they are formed. That they were not formed by the erosive action of

* The breadth of some is even less than I have stated.

water is apparent, because the salient points on one side (and the fracture is still sharp) have their re-entering points on the other; and, in fact, a convulsion of nature might again close them, in which case they would dovetail and fit exactly.

All the mountains in this part of Beloochistan exhibit the same effect of great disturbance, and much of the drainage of the country is at present effected through such fissures. The range to which the name of "Trukkee" is applied, is the most remarkable in this respect. These clefts extend even to the sandstone of the outer ranges; but the rock, being there of a more yielding nature, has suffered from the action of the elements, and the clefts (or passes) are wider, while the limestone usually exhibits them in their original sharp escarpments. I have reason to think that this nummulitic limestone extends over a very large tract of country, specimens brought from the vicinity of the Tukht-i-Sulliman having been shown to me by Lieutenant Cunningham, of the Bengal Engineers, which certainly belonged to the same formation. A similar rock is used for architectural purposes at Cantuel, and it takes, I was told, a tolerable polish. At Num, where I first came upon this limestone, it dips at about 20° south, passing in that direction beneath the conglomerate and sandstone, about a mile and a half further to the north. At the pass leading to the Deyrah Valley there is a remarkable slip or fault of the limestone strata, the dislocation amounting to about 300 feet. The limestone at the base here dips at about 20°, that above being nearly horizontal; and at the upper margin of the fault there are some of the strata hanging at various angles. This fault extends east and west of the pass for many miles.*

From this pass, proceeding north, the stratification is nearly horizontal as far as Coombe, a place about 2,100 feet above the sea. From Coombe, in a northerly direction, the limestone gradually obtains a dip to the north, amounting at its base to about 20°, and then becomes lost beneath low sandstone hills. I was unable on the line of march to give these interesting sandstone hills the examination they merited; they are composed of various coloured sandstones, with the strata dipping in a northerly direction at about 10°, or often less, thus corresponding so far in dip with the limestone; but the point of connection between the latter rock and the sandstone escaped my observation: this is to be regretted, as the subject is one of importance. These hills are interesting from the vast quantity of fossil bones and fossil wood which has been entombed within them; both are scattered about in vast profusion, and many cartloads of the bones could be collected from off an acre of ground.

The wood bears the appearance of having been drifted and water-

* The point of fracture exposed is highly glabrous, as if it had been exposed to a grinding action.

worn previous to fossilisation. I noticed palms and dicotyledonous trees, one of which had a structure resembling pine; some of the broken stems had a diameter of two feet, and the quantity exposed upon a small area was truly wonderful. I could only collect as many of the bones as I could carry on my own person, but amongst these are bones of the mastodon or elephant, portions of the tusk of the same (no molars were observed), part of the jaw of hippopotamus, various bones of crocodiles with broken jaws of the same, and many others which it will take time to make out. Thus it would appear, that on the northern and southern base of this limestone range (the first proceeding northwards from the Desert), there are strata having the same character, and that in both places similar fossil bones are found imbedded in a loosely cemented gravel, containing shells of Paludina and Cardium.

About five miles to the north, advancing towards the Deyrah Valley, a deep-bedded boulder conglomerate is met with, and one mile further the nummulitic limestone again crops out, the strata dipping north at about 45°. This range of limestone forms the southern side of the Deyrah Valley, and, it will be observed, dips into it; at the base it supports a stratum of conglomerate which is lost in the valley.

The Deyrah Valley stretches nearly east and west, corresponding with the mountain ranges; its mean breadth is about four miles, and its length perhaps forty miles. The soil is alluvial, and is in many places covered with boulders of nummulitic limestone.

The northern side of the valley is flanked with a range of hills composed of stratified boulder conglomerate. The boulders are nummulitic limestone, and the strata dip into the Deyrah Valley at angles varying from 20° to 35°; the northern aspect of this range is precipitous.

Immediately north of this conglomerate there is a very narrow valley abutting at the foot of the Trukkee nummulitic limestone range; this valley is broken by many small hills of a conical shape, composed of calcined clays of various colours, containing sulphur and scoria, and these seem to have been volcanic vents, emitting gaseous vapours, and perhaps occasionally ejecting stones, but never lava. No igneous rocks exist in the country visited, nor is any rock older than the nummulitic limestone to be found.

The Trukkee range, at the foot of which these appearances are presented, is composed entirely of nummulitic limestone, and attains an elevation of about 3,000 feet above the sea. The strata dip southwards towards the Deyrah Valley, at angles varying from 45° to 60°, and they form a continuous mural barrier, or a natural fortification on a stupendous scale, through which there are many passes formed by clefts in the manner noticed above. I traced this range, holding the same mural character for about seventy miles from east to west, and I also noticed other ancient conical hills at its base about twenty miles east of Deyrah.

Near the foot of the same range, at Kissooker, there is a tepid spring. At the time I noted its temperature, the air was 70° and the spring 71° of Fahrenheit. There are other tepid springs in these hills, one of which, at Doza Khooshtee, bursts up through a fissure in the limestone; but I did not note its temperature. From the appearance of the limestone which, in many plaees at Doza Khooshtee, is rapidly disintegrating, and from some caleined clays which I noticed, there is little doubt that an old volcanie vent existed in that neighbourhood.

The Deyrah valley requires further notiee, and appears to have been formed by subsidenee, but, however that may be, I am certain that the conglomerate at one time rested on the limestone, beeause there are still detached portions of it resting conformably on the limestone.

The opposite, or southern side of the Deyrah Valley exhibited the same evidenee, although not so distinctly, and a beautiful seetion of the limestone is seen in the pass, or cleft, through the Trukkee Hill. The floor of the pass is on a level with the base of the mountain, and the higher (outer) strata are full of fossils; but moving onwards through the pass and towards the north, the limestone becomes of a lighter colour, and further on obtains a slaty stratifieation containing few fossils. From this point to the Murray Hills there are numerous confused and broken hills at a lower elevation, whieh have undergone great disturbance, but I was unable to inspect them elosely.

The Murray Hills are composed of nummulitic limestone, they present a precipitous escarpment to the southward, and the stratification is nearly horizontal. The range is higher than any of those between it and the Desert.

No minerals of any account were met with; sulphur and alum exist, but not in sufficient abundance to be of eommercial value; but alum is worked further to the eastward, although not in the district visited. Iron exists in small quantities; iron pyrites abound in nodular masses in the limestone, and there are gypseous veins at Doza Khooshtee. When notieing the pale yellow variety of limestone, I forgot to mention that it often contains nodular, ramified or tabular masses of flint, whieh frequently manifest a resemblance to stems of marine algæ and sponges. Doza Khooshtee and Trukkee are two remote points which exhibit this formation. A white marble, whieh would answer for statuary purposes, is found in the Trukkee range.

The aspect of the country is barren in the extreme, but in some plaees there is sufficient soil to repay the cultivation. Near the anticlinal axis of the first limestone range the disintegrated limestone forms a good soil, which has been cultivated. The alluvium of some of the valleys is also fertile, partieularly that of Deyrah. The native plants of this region are peculiar, but few in number, not exceeding 200 speeies.

The hasty examination given to these mountains will, I hope, be a sufficient apology for many defects in the details now furnished. It requires more time than a marching soldier can command to follow out fully a geological inquiry in a broken and mountainous country. It happened more than once that I passed over most interesting ground during the night, and even in the daytime other duties often required my undivided attention.

I cannot close this report without tendering my sincere thanks to His Excellency Major General Sir Charles Napier, G.C.B., for the assistance so liberally afforded in giving me carriage for my specimens—an instance of regard for the interest of science rarely manifested in India.

*Description of the Fossils from the Nummulitic Limestone of Beloochistan.**

POLYPARIA, three or four species.

ECHINODERMATA.

Cidaris Schmidelii, Goldf.

A large and fine specimen probably referable to this species, having spines similar to those described by Goldfuss. His species, however, belongs to the Jurassic series, so that the identity may be doubtful.

Spatangus acuminatus, Goldf. Sow. Geol. Tr. 2nd ser. vol. v. t. 24, f. 23.

——— *obliquatus*. Sow. G. Tr. v. t. 24, f. 22.

——— *elongatus*. Sow. G. Tr. v. t. 24, f. 24.

In the collection there is a crushed specimen nearly allied to this species, but it appears to have had a more ovate form. There are also three or four other species of Echinodermata.

FORAMINIFERA.

Fasciolites ellipticus. Sow. G. Tr. v. t. 24, f. 17.

Nummulites acutus. Sow. G. Tr. v. t. 24, f. 13.

Lycophris Ephippium. Sow. G. Tr. v. t. 24, f. 15.

——— *dispansus*. Sow. G. Tr. v. t. 24, f. 16.

CRUSTACEA. One or two species.

MOLLUSCA.

Cardium ambiguum. Sow. G. Tr. v. t. 24, f. 2.

Ostrea callifera, Lam. Sow. G. Tr. v. t. 24, f. 7.

Chama ——— ?

Spondylus ——— ?

Pecten. Two species and some casts of other genera of conchifera.

Nautilus ——— ?

Globulus obtusus. Sow. G. Tr. v. t. 24, f. 10.

Cypræa depressa. Sow. G. Tr. v. t. 24, f. 12.

Turbinellus bulbiformis. Sow. G. Tr. v. t. 24, f. 11.

An imperfect cast of a specimen probably belonging to this species.

Seraphs ——— ? A cast only. The species is the same as that obtained from Baboa Hill, and near to *S. convolutus*, Min. Con.

There are also some other casts of univalves and a Serpula, but they are indeterminable.

* The description has been drawn up by Mr. Morris.

On the Geology of Part of the Sooliman Range. By Dr. A. Fleming, E.I.C. *In a Letter to Sir R. I. Murchison, F.R.S., F.G.S., Pres. R. Geog. Soc.**

With the exception of occasional patches of corn crop now in ear (March), the whole central district of the Derajat, between the cultivated belt, or Kuchee, along the Indus and the foot of the Sooliman Range, is a barren alluvial plain, thinly dotted with dwarf jungle bushes of wild caper and petoo (*Salvadora Persica*), and in some places covered with a thick crop of lana (a species of *Sulsola?*), by burning large quantities of which the natives obtain a coarse kind of carbonate of soda (Sujee). This latter plant is only found on plains liable to be flooded *moderately*, and in which saline matter is abundant. Its present habitat supplies both the above conditions, for although the river-inundation never reaches it, yet, whenever rain falls in the hills, hundreds of mountain torrents escape from the various ravines and passes, and for a time convert the whole country into a sheet of water, which is, however, drunk up by the thirsty soil long before it reaches the Indus. As very little rain falls in the Derajat, the natives for agricultural purposes (wells being very scarce, and water found in them at from 100 to 150 feet deep) endeavour to detain the water in its onward course as long as possible, and for this means all the country is traversed by "bunds" or embankments, parallel to the hills, inside which they plough the ground and sow their scanty crops. As but little rain falls even in the hills in the cold weather, the cold weather or wheat crop is a very precarious one, and in a season of drought, such as this has been, almost a failure. The rain or hot weather crop, consisting of millet, Indian corn, &c., is a much more successful one, and of more importance. Water-power and population only are wanted to convert the whole district referred to into a rich corn-field, the saline matter it contains not being in such quantity as to be deleterious to wheat crops, if means of irrigation are available.

Separating the alluvial desert tract just noticed from the Sooliman Ranges, is a belt of boulder deposit, varying in breadth from two to four miles; the boulders are larger and more numerous as we ascend towards the hills, on the strata of which they rest unconformably. The boulders occurring in this deposit appear to have been derived from

* Reprinted from the Quarterly Journal of the Geological Society of London, vol. ix. part i. p. 346.—Ed.

the constituent rocks of the Soolimans. Some are of primitive or metamorphic rocks, but they chiefly consist of the sandstones and boulders forming conglomerates in the first or outer range of hills. These latter are of a character identical with the later Tertiary (miocene ?) or Sewalik strata of the Salt Range. They present in outline the same jagged character, and consist of alternations of sandstone (calcareous, and sometimes only indurated sand), calcareous grit, conglomerates, and indurated clays; and they everywhere present on their surface a saline efflorescence, more or less distinct. In the outer range they dip at a very high angle to the E., and in some places are almost vertical. In the Mungrota or Sungurh pass, into which, on the 24th, I made a short excursion, accompanied by troopers with loaded carbines, these miocene (?) strata occur on either side with an easterly dip for about two miles, the harder ridges of sandstone which cross the pass forming as fine natural defences as could anywhere be found; and, indeed, the Bosdar tribe, who inhabit the hills at this point, are by no means loath to use them as such, while covering the retreat of any of their brethren who may be returning from a foray in the plains.

On proceeding about two miles up the Sungurh Pass, in a nearly west direction, the miocene (?) strata give place to beds of nummulite limestone, enclosing several species of nummulite, and one very large species nearly an inch in diameter. Beds of this limestone alternate with dark bituminous clays, in which an *Ostrea*, similar to one I got in the Salt Range, is abundant, and under these a dark brown slaty calcareous sandstone, also containing numerous examples of a similar shell. Beneath this sandstone nummulite limestone again appeared, and *seemed* to form a second range, the strata of which dipped to the E. conformably at a similar and very high angle under the miocene (?) strata. Not deeming it safe to go beyond the nummulite limestone range; and having reached about three miles inside the pass, I was obliged to return. I hope yet to have an opportunity of seeing what the inside of the Sooliman Range is made of, though I have no doubt it is merely a lower extension of the Salt Range.

The two outer ranges (for such they appear, looking at them from the plain) are evidently portions of an anticlinal slope, the main or chief range (Kala Roh, or Black Mountains, as it is called) having a distinct *westerly* dip, with a scarped face to the E. In several of the water-courses I have seen boulders of *Productus limestone*: and, as in several passes brine-streams occur, and masses of gypsum of a most saliferous aspect, I feel assured the time will come when the salt formation will be found. I cannot learn that salt ever has been found, though natives have told me that the red marl, similar to that which imbeds the salt in the Salt Range, does occur in the interior of the hills. The annexed

rough sketch will make the structure of the range more distinct.* As the Sooliman High Range† is of considerable height (pines are visible on it opposite to where I now am), it is most probable that in some of the passes which traverse it some most valuable sections are obtainable, and probably the formation on which the saliferous strata rest may be ascertained. Among the boulders in the pass I visited, I saw a sandstone which I believe belongs to the saliferous series. The difficulties, however, in following out any researches in these hills are very great. One cannot go unarmed or without a party, and hence the explorer cannot follow the by-ways but must keep to the high-ways. The Bosdars on the Dera Ghazee Khan frontier, and the Kusranees and Shioranees on the Dera Ismael Khan frontier, are all robbers, and live by plunder, and would be only too glad to get hold of any of us, as we are here to cut them up if they appear on the plains intent on a foray.

[On January 18, 1853, Dr. A. Fleming had the opportunity of riding up with an escort to the mouth of the Vidon Pass, opposite Dera Ghazee Khan. Here also he observed the deposits above noticed, and found boulders of white quartzite and of *Productus limestone*.]

On the Geology of a Part of Sinde. By H. B. E. Frere, Esq. Commissioner in Sinde. *In a Letter to Colonel Sykes, F.R.S., F.G.S.*‡

I have taken the opportunity of the 'Duke of Argyll' going direct from Kurrachee to London, to send a couple of cases to your address. They contain a number of tertiary fossils, chiefly bones of Mammalia, very much resembling the Perim fossils ; these were collected by Mr. Arthur Young, the Deputy Collector of Sehwan, who, if they are of any interest, would wish you to keep for your own collection any you like, and to present the rest, if you consider them worthy of presentation, to the India House, or any other public museum. Any account of what they are would be most acceptable, and any call for further information,

* See Pl. XXII. fig. 7.—*Section of a part of the Sooliman Range.*

1. Alluvium.
2. Boulder deposit.
3. Alternations of sand, sandstone, calcareous grit, conglomerates, and indurated clays.
4. 1. Nummulite limestone, alternating with dark bituminous clays with *Ostrea*.
   2. Dark brown slaty calcareous sandstone, with *Ostrea*.
   3. Nummulite limestone.

† The Sooliman generally is destitute of trees and almost of brushwood ; and its resemblance to the Salt Range is very great.

‡ Reprinted from the Quarterly Journal of the Geological Society of London, vol. ix. p. 349.—Ed.

or more specimens, would be carefully attended to. Neither he nor I have been able to reach the exact locality where they are found.

It is in the hills SW. of the Munchar Lake and Sehwan, and about half way to Sháh-billáwull, but on the east side of the Hubb River. I must have been very near it in traversing the hill-route from Kurrachee to Sehwan, in November 1851, but all the rocks I saw were nummulitic limestone greatly contorted, the ranges of hills being generally "wrinkles," as it were, of nummulitic strata, which could be for the most part traced with great clearness from the valley on one side over the hill and down into the valley on the other side (see diagram).*

The western slopes of the ranges (the general direction of which is N. and S.) were usually the least broken; but it was rarely difficult to trace the identical bed from valley to valley across the range, and for miles along the range. Though the strata were often not continuous, the dislocation of fragments was rarely so great as to prevent the original connection from being seen. The cross-valleys were generally not water-worn fissures, but huge cracks across the range, with the rocks on each side apparently little altered since they were rent apart. In one place a fissure of this kind gave a section of the range certainly not less than 1,000 feet in depth; it was nummulitic limestone from top to bottom. The skirts of the hills and bottoms of the valleys parallel to the main ranges were often marked with alluvial deposits, conglomerates of nummulitic pebbles, and gravel, and I found, in more than one spot, unmistakeable evidence of such valleys having been once lakes.

The only two good sections which I got of the strata in such situations, were, first near Meer Ahmed-Khan-ka-Tanda, where a hot spring rose at the head of a small cross-valley in the nummulitic strata, which at that spot were nearly perpendicular. Upon these, less inclined, were beds of indurated mud and shale, and upon the skirts of the latter, down into the plain and across to the opposite range of hills, were beds of gravel and sandy conglomerate, at first inclined, but, away from the hills, gradually becoming nearly horizontal (see diagram, *loc. cit.*).

I suspect that the bones are found in a similar deposit, but my belief is founded only on the reports of the natives who found the bones. I failed to find any remains in either the gravel or shale, save one small splinter of bone in the gravel.

The other section was near Kujoor, where one of the cross-rents above described cuts right through a range of hills.

* Pl. XXII. fig. 8.—*Section of Nummulitic Range between Kurrachee and Sehwan, in Sinde, with the accompanying shale and gravel beds, as seen in the cross-valleys.*

1. Beds of gravel and sandy conglomerate. } ? with bones.
2. Variegated marls and shales, or indurated mud-beds. } ? with bones.
3. Nummulitic limestone, forming the Range.

The indurated mud or shale is frequently of various brilliant colours, white, and all the shades of yellow, brown, and red, which oxides of iron give. At the spots above mentioned it was apparently resting on the nummulite rock, but more frequently it occurs where this rock is most dislocated, and appears to have been forced up from below. This is very frequently observable on the eastern slopes of the hills, which, as before observed, are usually more precipitous and broken than the western slopes. In two spots this eruption (?) of coloured marls and shales covers an area of several miles square. One is at Runnee-ke-kote or Mohun-kote, where the shale is sufficiently aluminous to afford alum for commercial purposes; the other is about eight miles from Sehwan. In both places, tables of nummulitic limestone are sometimes seen supported on the coloured marls, but, in general, the limestone has disappeared.

There are numerous unmistakeable traces of volcanic agency. Springs are rare, but what exist, generally at intervals of from ten to twenty miles, are usually hotter than the outer air; not exceeding, however, in any spring which I saw, 109° Fahr. Orifices, whence hot air and steam issue, are not uncommon, and in more than one spot, on nearly level plains, I found small eruptions of fused matter, forming mounds often not more than a few hundred yards in circumference. Around the edge the blocks of nummulitic limestone (or conglomerate of pebbles of such rock) were hardly disjointed from the nearly level surface-stratum. Higher up the blocks became more dislocated and discoloured, as by fire; a little higher they were more or less fused, and at the top of the heaps had often the appearance of vitrified slag.

The water of the warm springs in the Sehwan hills has generally a trace of sulphate of lime; sometimes, indeed, is highly impregnated with it.

Some months ago, I forwarded, through the Bombay secretariat, a box of specimens of the sulphurous earth found in some localities near Kurrachee. It is not, I expect, pure enough to be worked economically.

On the Indus, March 19*th*, 1853.

Descriptions of some of the larger Forms of Fossilised Foraminifera in Sinde, with Observations on their Internal Structure. By H. J. Carter, Esq., Assistant Surgeon, H. C. S., Bombay. With a Plate.*

[Presented 11th November 1852.]

Through the kindness of several officers of the Bombay Army, access to the Society's Museum, and my own observations in Sinde, I have become acquainted with many, if not most, of the larger forms of fossilised Foraminifera of that country; and as descriptions of them may prove acceptable to those engaged in the study of geology in Sinde and elsewhere, I have much pleasure in offering them for publication in the Society's Journal, should they be deemed worthy of it.

I wish it had been in my power to point out the particular parts of the Nummulitic Series in which they are found, but as we are perfectly ignorant of all detail of this kind respecting Sinde, it must be left for future opportunity to develope.

In the description of these Foraminifera, I shall not confine myself to their external characters alone, for, generally speaking, this would be useless, but, having studied them by sections, shall also allude to their internal structure, which, though already given most faithfully and elaborately by Dr. Carpenter (Quarterly Journ. Geol. Society, vol. vi. p. 21), yet there are still a few deficiencies, which I shall endeavour to supply, and some observations which can only become intelligible when the forms of *Operculina*, *Assilina*, *Nummulina*, *Alveolina*, *Orbitoides*, *and Orbitolites*, are considered together and described successively.

The distinguishing characters of these genera, familiar, at least in name, to all who are acquainted with the classification of Foraminifera in D'Orbigny's "Foraminifères fossiles du Bassin Tertiaire de Vienne," and in his "Cours élémentaire de Paléontologie et de Géologie Stratigraphique," I shall here premise, that the reader, if inclined to study them, may have no trouble in immediately referring to the same sources from which I have derived my guide.

* Reprinted from the Journal of the Bombay Branch of the Royal Asiatic Society, with alterations and additions, vol. v. p. 124.—July 1853. See also Ann. and Mag. Nat. History, vol. ii. p. 161.—1853.—Author.

Order III. HELICOSTEGUES.

Fam. 1. NAUTILOIDÆ.

Genus NUMMULINA, D'Orbigny.

"*Shell*, free, equilateral, orbicular or discoidal, thick, encrusted, without appendices at the border, formed of a *spire* embracing, with whorls very near together and numerous; the last always marked in the young animal, but often impossible to be found in the adult. *Chambers*, small, short, near together, very numerous, the last projecting in the young animal, but indistinct in old individuals; pierced by an opening transverse, linear, against the turn of the spire, often concealed in the adult."

ASSILINA, D'Orbigny.

"*Shell*, free, equilateral, orbicular or discoidal, very compressed, formed of a *spire* embracing only in the young animal. Afterwards whorls apparent, and without appendices at the border. *Chambers*, small, short, very numerous, the last projecting in the young animal, but not so in the adult, each pierced by an *opening* against the turn of the spire."

"*Relations and Differences.*—The Assilines, like the Nummulines, have a projecting mouth when young; but they are distinguished by all the turns of the spire being apparent in the adults, instead of being embracing."

OPERCULINA, D'Orbigny.

"*Shell*, free, equilateral, oval or discoidal, very compressed, formed of a *spire* not embracing, regular, equally apparent on both sides, turns contiguous, and increasing very rapidly. *Chambers*, numerous, narrow, the largest projecting beyond all the rest, pierced at all ages by an opening which is visible, triangular, against the turn of the spire."

"*Relations and Differences.*—It is evident, that by the situation of its opening, this genus comes near to the Assilines; but it is distinguished from them by its opening being triangular instead of a transverse slit; and by its chambers increasing regularly, without becoming narrow towards the opening."

ALVEOLINA, D'Orbigny.

"*Shell*, free, regular, equilateral, round, oblong, or elongated, in the direction of its axis, not variable in its enlargement, composed of a very regular *spire*, embracing at all ages; whorls often very near together, not formed of many chambers, elongated transversely, divided into a great number of capillary cavities by partitions longitudinal to the whorl, the openings round, numerous, and in lines transverse to the whorl."*

* Foram. Foss. du Bassin Tert. de Vienne, par M. Alcide d'Orbigny.

CYCLOSTEGUES, D'Orbigny.*

"Animal composed of numerous segments placed in circular lines. Shell discoidal, composed of concentric chambers, simple or multiple; no spire."

"*Cyclolina*, D'Orb. 1839.—Shell discoidal, each chamber pierced by a number of pores, making an entire circle round the rest."

"*Orbitolites*, Lamarck, 1801.—(*Orbulites*, 1816, non *Orbulites cephalopodes*.) *Marginopora*, Quoy et Gaimard, 1836.—Shell discoidal, plane, equal, and encrusted on both sides, presenting concentric lines. *Chambers* numerous in irregular transverse lines, only visible at the border."

"*Orbitolina*, D'Orb. These are *Orbitolites* with unequal sides; the one convex, encrusted, presenting concentric lines; the other concave, not encrusted; presenting numerous chambers, in oblique lines upon the side at the circumference."

"*Orbitoides*, D'Orb. Shell discoidal, convex on both sides, formed of a single range of chambers, round the disc, very thickly encrusted about the middle, and presenting either radiating lines or granulations."

Observations.

To these characters I would add the following observations before proceeding further, beginning with the distinction between the genera *Assilina* and *Nummulina*.

This is said to consist chiefly in the spire not being embracing in the former, for such it appears to be to the naked eye, but if we make a vertical section of *Operculina*, which, from its extreme thinness, is still further removed from *Nummulina* than *Assilina*, while it is closely allied to the latter, it will be seen, under a magnifying power, to be formed of several layers, which may be traced from the centre to the circumference, showing that, as the turn of the spire is progressing, the deposition of new material not only takes place at the margin, but on both sides of the shell generally, in a line from the last chamber in process of development up to the central or first-formed one. If, then, this can be seen in a shell so thin as that of *Operculina*, and so closely allied to *Assilina* as this is, how much more evident should it be under the same circumstances in *Assilina*, which is so much thicker. It is so, and hence, D'Orbigny's grand distinction, of the spire not being embracing in *Assilina*, is more apparent than real; notwithstanding, it is sufficient for common purposes, but a surer one is the *absence* of chambers both above and below the central plane.

The division of *Nummulina* into subgenera—

* Cours élément. de Paléontologie et de Géologie Stratigraphique, par M. Alcide d'Orbigny.

It appears to me that this may be advantageously done by separating those in which the septa extend from the circumference to the centre in more or less continued sinuous lines (Pl. XXIII. figs. 11 and 15), from those in which the lines are so branched and inosculate as to present a densely reticulated structure (fig. 12).

Such differences have already been alluded to by Dr. Carpenter. (*Loc. cit.*)*

In the latter subgenus would then come *Nummulites acuta*, Sowerby, which borders close upon *Orbitoides*, from possessing this reticulated structure in its chambers, and therefore a comparatively less perfect development of this part of the spire, with a tendency to an abrupt prominence in the centre, and an expanded thin margin.

From *N. acuta* we should then pass on to *Lycophris dispansus*, Sowerby, where the spire is still more incomplete, and then to *Orbitoides Mantelli* or *Orbitolites Mantelli* (for we shall see hereafter that we must make this an *Orbitolite*), where the central plane of chambers is hardly distinguishable and the spire entirely lost.

In the last two genera I have been at much pains to ascertain if the rows of chambers in the central plane are arranged spirally or concentrically, and I think that I have been as successful as, under the circumstances, we can expect to be.

For some time I was unwillingly obliged to yield to the opinion of D'Orbigny, that the rows of chambers commenced concentrically, for, having taken adult specimens of *Lycophris dispansus* and *Orbitoides Mantelli* for sections, I found the centre in each species invariably filled with calc-spar, which, apparently, was surrounded by circles of chambers at its circumference, that is, where the latter began to appear. Hence I had given up almost all hope of being able to determine this satisfactorily, when I conceived that the origin of this structureless centre might be owing to a decay of the central chambers in the adult animals only, followed by an infiltration of calc-spar into it during fossilisation; and that, if I took very young individuals, I might obtain what I wanted. Accordingly, I made sections of specimens not larger than the 24th part of an inch in diameter, and found just what I had expected, viz. the centre in its natural state, that is, filled with chambers to the central point.

* Omit this paragraph, as it is a misconception of the author's meaning. MM. the Vicomte d'Archiac and J. Haime have noticed this error; but they were nevertheless engaged at the same time as myself in making the distinction to which I allude, viz. the dividing of the simple from the reticulated-chambered Nummulites. See their beautiful work entitled "*Description des Animaux Fossiles du Group Nummulitique de l'Inde*," 4to, 1853, pp. 72 and 343, where they have divided this proposed "Subgenus" into two "Groups," terming them respectively "*Reticulatæ*" and "*Subreticulatæ*," thus establishing in another way the division above suggested.

I will now shortly describe the central planes in both these species, reserving a more particular account of them until we come to the descriptions of the species themselves.

In *Lycophris dispansus* the central plane is extremely, though uniformly, thin throughout, and only one chamber deep. The chambers commence in an imperfect spire, round a central spheroidal or oval cell, not much larger than the chambers themselves generally. Around this cell are a few chambers, which have—one a semilunar, and two or three the pear-shaped forms of the chambers commencing the spire in the nautiloid forms of Foraminifera (compare fig. 26, pl. xxii. with fig. 8,* pl. xviii. vol. iv.) ; the rest are more or less polygonal. From these chambers (about seven in number) as many rows of others fly off from the centre in whorls similar to the sparks of a rotatory firework, but these rows soon diminish in breadth, and end more or less abruptly upon the back of each other ; when another set rises from their circumference, which takes a larger latitude ; and so on successively, a series of whorls or wreaths follows upon the back of each other, until the rows appear to form concentric circles, still every here and there dipping inwards, or suddenly terminating on the preceding ones, even to the circumference. This is the appearance presented by the central plane ; but the real spire must be traced across the rows in the position that it would be in Foraminifera, wherein it is more perfectly developed,—if, indeed, it be traceable at all.

In *Orbitoides Mantelli*,† however, the central plane is very different ; here it is not uniformly thin throughout, but thin in the centre and thick at the circumference, from the cells being only half the size in the former that they are in the latter ; they are also all spheroidal, or elongated vertically, and not quadrangular. When they are elongated vertically, this seems to depend on two or more running into each other in this direction ; hence the central plane, instead of being composed of only one layer of quadrangular chambers, as in *O. Mantelli*, is composed of a plurality of layers of spheroidal ones ; this, together with the smallness of the central cells, their great similarity, and the whole plane which they compose being more or less wavy, renders it almost impossible in the section to detect the central cell itself, or to determine whether the others are arranged around it in concentric circles ; while it seems almost equally impossible to trace them in circles towards the circumference, to determine this, where their arrangement even is most distinct.

Hence it would appear that D'Orbigny is not warranted in giving the distinguishing character of concentricity to the rows of chambers in his order *Cyclostègues*, for in his three first genera, which are all alike

* Ann. and Mag. Nat. Hist. † Quart. Journ. Geol. Soc. vol. vi. p. 30.

in this respect, we have seen that it is almost impossible to determine this ; and in the last genus, viz. *Orbitoides*, of which *Lycophris dispansus* is a type, it is evident that it is not the case, but that the chambers are arranged subspirally.

That *Orbitoides Mantelli* should be included among the *Orbitolites*, and not among the *Orbitoides*, must also now be evident, from the striking differences that exist between it and *Lycophris dispansus*, and its identity in structure with *Orbitolites* generally ; while the intervening link between it and *Nummulina* is naturally supplied by *Orbitoides* bearing the characters above mentioned. It may be observed, that the cells of the central plane in *O. Mantelli* are elongated, and not spheroidal ; but the one seems to be as constant as the other, and the elongation vertically only to depend, as before stated, on the thinness above and below of the walls of the cells forming the central plane, which renders those parts imperfect or imperceptible in the vertical section, and makes the cells appear to run into one another ; while the opaque material or intercellular substance showing out at their sides gives them that septal, and at the same time quadrangular form, which approximates the whole central plane in appearance to that seen in the vertical section of *Orbitoides* and *Nummulina*.

The other observations which I have to make on the structure of these two genera, will be better understood in connection with their species when respectively considered.

As the list of synonyms of the discoidal Foraminifera already noticed is very great, for the short time they have excited attention,* at the same time that their descriptions are very few, and not within my reach, I shall avoid as much as possible introducing new names here, in hope that others who are more favourably situated may be able to do this from my descriptions and figures, if required, or that I may be able to do it myself at some future period, when I have better means of comparing the specimens of different localities than I at present possess.† Meanwhile, as so little has been done in the subject, I am not without hope that that which I have now to offer may be found useful.

In order of description I shall not exactly follow D'Orbigny's arrangement, that I may be the better able to show the transition from the simple to the more complicated forms of discoidal Foraminifera. Thus I shall place *Operculina* before *Nummulina*, &c., *Alveolina* after

* See Murchison on the Structure of the Alps (Quart. Jour. Geol. Soc. vol. v. p. 309), also MM. le Vicomte d'Archiac and J. Haime, *op. cit.*

† This has, for the most part, been effected now by the celebrated authors just mentioned and by myself through the assistance of their valuable work already noticed ; as will be seen, by comparing the present with the original edition of this paper.

N. obtusa, Sowerby, and before *N. acuta*, id.; and then pass on to *Orbitoides* and *Orbitolites*.

The figures in the Plate are intended to represent the largest specimens of the species I have met with respectively; and where the characteristic structure externally has been too minute to be seen by the naked eye, a small portion has been magnified in the centre. Indeed, in almost all, the lines and markings are larger than they are naturally, and are therefore represented as seen under a magnifying glass of low power, for in no other way could these characters be given.

As a typical description of *Operculina* and the structure of foraminiferous shells generally, I must refer the reader to my observations on *O. Arabica*,* by a perusal of which an understanding of what follows will be much facilitated.

OPERCULINA, D'Orbigny.

1. *Operculina inæquilateralis* (H. J. C.). Inequilateral, oval or discoidal, thin, horizontal or wavy; centre prominent, margin thickened, rounded, cord-like. Spire more or less irregular, more apparent on one side than the other, consisting of three whorls, concave on one side, flat on the other, increasing rapidly from a central cell. Chambers numerous, narrow, slightly reflected. Septa reflected, more apparent on one side than the other. Diameter of largest specimens 5-24ths of an inch (pl. xxii. figs. 1, 2).

Loc. Muskat, in Arabia.

Obs. This species differs a little from D'Orbigny's characters in being inequilateral, but the difference between the two sides is so slight that it cannot be referred to any other genus. The intercameral communication I have not been able to make out, and although D'Orbigny almost invariably gives its shape and position in the nautiloid Foraminifera as a distinguishing character, yet I have hardly ever been able to see it satisfactorily in any of the species that I have examined.

O. inæquilateralis is a characteristic fossil of a thick, pink-coloured, silico-calcareous, sandy stratum at Ras Ghissa, the first little cape south of Muskat, which is a port on the north-eastern coast of Arabia opposite Sinde. I have inserted its description here chiefly for the purpose of commencing with the simplest form of nautiloid Foraminifera, and also from its proximity in locality to Sinde.

2. *O. Tattaensis*, D'Archiac and J. Haime. Equilateral, discoidal, plane or slightly wavy, thin. Centre prominent, and presenting granulations or small tubercles, projecting more in the young than in the adult state; tubercles, situated over the septa, one to each; margin slightly thickened, rounded, cord-like. Spire more or less regular, equally evi-

* Ann. and Mag. Nat. Hist. vol. x. 1852, and Bombay As. Soc. Journ. vol. iv. p. 430.

dent on both sides; consisting of six whorls, gradually increasing to the last, which is 1-24th inch broad; each whorl overlapping or embracing, with its internal border, the external margin of the preceding one, which is rounded and cord-like. Chambers numerous, reflected; septa reflected, apparent on both sides. Diameter of largest specimens 5-12ths of an inch; thickest part, which is the margin, 1-36th of an inch (figs. 3, 4).

Loc. Sinde; in company with *Alveolina*, near the town of Tatta.

Obs. In this species, which is twice the diameter of the last, and generally more horizontal, the whorls are more numerous, and the spire increases more gradually. I could not discover the intercameral communication.

Assilina, D'Orbigny.

1. *A. irregularis*, H. J. C.; *N. granulosa*, D'Arch.* Equilateral, discoidal, more or less wavy, compressed, thin. Centre depressed, margin thickened, rounded, cord-like. Spire more or less irregular, projecting on both sides, excepting in the centre, where it is nearly obscured; consisting of nine whorls, increasing gradually towards the penultimate, which is 1-12th inch wide; each whorl overlapping or embracing, with its internal border, the external margin of the preceding one, which is thickened, rounded, and cord-like throughout the spire. Chambers subquadrangular, oblong, irregular in size, presenting a number of minute granulations over their surface externally. Septa straight, radiating, and a little reflected, evident on both sides, except in the centre. Diameter of largest specimens 11-12ths of an inch; thickest part, which is the margin, 1-24th of an inch (figs. 5, 6).

Loc. Sinde.

Obs. This, although somewhat resembling the last-described species of *Operculina*, differs from it in being much larger and coarser in form, in the extreme irregularity of its spire and development generally, the depression in the centre, the obscurity of the three first whorls, and in the penultimate whorl being the broadest. I could not discover the intercameral communication. The young of both this and the next species are covered with high granulations, especially towards the centre.

2. *A.* —— ? *Nummularia exponens*, Sowerby.† Equilateral, discoidal, slightly wavy, thick, smooth, depressed in the centre, angular at the margin, presenting broken curvilinear lines on the surface with minute granulations between them, arranged in a spiral form, radiating from the centre, indicating the position of the spire and septa. Internally whorls more or less wavy, more or less irregular in breadth, the largest

* *An. Fos. Num. de l'Inde*, pl. x. fig. 11, &c.

† Trans. Geol. Soc. London, 4to, vol. v. Colonel Sykes on Fossils from Cutch, pl. lxi. fig. 14. *An. Fos. Num. de l'Inde*, pl. x. figs. 1—10, *et* p. 343. This is the typical form of MM. le Vicomte d'Archiac and J. Haime's 6th and last Group of Nummulites, viz. *N. Explanatæ*.

between the centre and the circumference (2-48ths of an inch broad); about nineteen whorls may be counted within half an inch of the centre. No chambers above or below the central plane. Diameter of largest specimens 1½ inch; thickest part, which is between the centre and the margin, 3-12ths of an inch (figs. 7, 8).

Loc. Sinde.

Obs. This closely approaches *Nummulina* from its size and thickness; the spire and septa, however, are still more or less visible externally, but the increased thickness of the shell obscures their prominence, and gives the surface more smoothness and uniformity. The edge is thick and angular, instead of being round and cord-like, as in the foregoing species, and the whole now closely approximates a nummulite.

NUMMULINA, D'Orbigny.

1. *Nummulites Carteri*, D'Archiac and J. Haime. Equilateral, discoidal, more or less wavy, thin, gradually diminishing in thickness from the centre towards the margin, presenting on the surface numerous small papillæ or granulations between sinuous lines running more or less irregularly from the centre to the circumference, the latter being the most evident of the two in the young shell. Internally whorls more or less wavy, more or less irregular in breadth, the widest between the centre and the circumference (2-48ths inch broad); about twenty whorls may be counted within half an inch of the centre. Compressed chambers above and below the central plane. Diameter of the largest specimens $2\frac{1}{12}$ inch; thickness in the centre 2-12ths of an inch (figs. 9, 10).

Loc. Sinde.

Obs. The great point of difference between this and the last-described species of *Assilina* is the presence of the compressed chambers above and below the central plane in the former. The whorls here, therefore, are evidently what are termed embracing, and the centre is prominent on both sides instead of being depressed. This nummulite attains the largest size of any species that has come under my observation. It is only named provisionally by the authors above mentioned.

2. *N. millecaput?* Equilateral, discoidal, more or less wavy, thick, angular at the margin, presenting sinuous lines on the surface in close approximation, which extend from the circumference to the central prominence on each side, presenting a series of superficial whorls in the adult animal. Internally turns of the spire very numerous, more or less wavy and irregular in breadth, the widest between the centre and the circumference 1-48th of an inch broad; about forty-eight whorls may be counted within half an inch of the centre; compressed chambers above and below the central plane. Diameter of the largest

specimens $1\frac{6}{12}$ inch ; thickness in the centre 3-12ths of an inch (figs. 11, 12).

Loc. Egypt.

Obs. This differs from the foregoing species in its general thickness; the number and approximation of its sinuous lines, the absence of the small granulations or papillæ between them, and the greater number and narrowness of its whorls. The sinuous lines, although confused, and in whorls all over the surface in the adult animal, are nevertheless distinctly sigmoid in the young one, running from the circumference to the central prominence of the shell on both sides.

This specimen was brought from Egypt. It appears to be *N. mille-caput*. That figured by MM. Joly and Leymerie is $1\frac{1}{12}$ inch in diameter. Generally the nummulites of this kind from Egypt which I have seen (those of the Pyramids, to wit) have been about an inch in diameter, and about 2-12ths inch thick. I have inserted its description here, and figure in the Plate, for the sake of comparison, not having met with one of exactly the same kind in Sinde.

3. *N. obtusa*, Sowerby. Equilateral, more or less globular, compressed in the centre, obtuse at the margin. Surface presenting sinuous lines in close approximation, and in confused whorls in the adult animal, but simple and sigmoid in the young shell; extending from the septa at the circumference to the central prominence on each side. Internally whorls numerous, the broadest between the centre and the circumference; lines of the spire nearly as widely separated above and below the central plane as they are in the central plane itself. Chambers numerous, reflected; septa reflected. Diameter of the largest specimens 11-12ths of an inch; thickness 2-10ths; number of whorls thirty-three (figs. 13, 14).

Alveolina, D'Orbigny.

1. *Alveolina melo*, D'Orb.; *Melonites sphærica*, Lamarck. Spherical, equilateral, presenting longitudinal lines, which extend in a sigmoid form from apex to apex, and minute transverse parallel ridges between them, marking corresponding internal divisions of the chambers. Internally chambers fusiform, sigmoid, divided into hair-like spaces by transverse septa, which are the continuations of the ridges mentioned; the whole arranged in a spiral form. Diameter 5-24ths of an inch (fig. 15).

Loc. Sinde, Arabia.

2. *Melonites sphæroidea*, Lamarck; *Alveolina sphæroidea*, Cart. (D'Archiac *et* J. Haime), fig. 16.

Loc. Sinde, Arabia.

Obs. This has the same characters as the last, with the exception

of being larger, and a little elongated. Longest diameter 7-24ths of an inch; transverse diameter 6-24ths. Abounds about Tatta in Sinde, where it is well known by the name of "Tomra," and is made into strings of beads for Hindu pilgrims, and others of the Hindu faith. They are said to be prepared for this purpose by being repeatedly struck with a hammer, until the external layers, peeling off, leave a smooth surface.

3. *Fasciolites elliptica*, Parkinson (fig. 17).

Loc. Sinde.

Obs. This also has the same characters as the foregoing species, but is much elongated, almost cylindrical. Length 7-24ths of an inch; breadth 3-24ths. It abounds about Hyderabad, and near the Buran river, in company with *Cyclolina pedunculata*, to be hereafter described.

There is nothing to distinguish these species one from another but their spherical, spheroidal, and elliptical forms respectively. The two latter appear to have their peculiar localities in Sinde, and to be sparingly mixed together. On the south-east coast of Arabia, where they are also found in company with *Cyclolina*, the spheroidal form is most common. D'Orbigny has made them the last genus of his second section of nautiloid Foraminifera, but I have inserted their description here, to show the transition from the flat to the elongated forms of his *Helicostègues*.*

Let us now return to the descriptions of the other nummulites which will be found to differ from the foregoing in the absence of the sinuous lines on the surface, and in the presence of the reticulated structure mentioned.

NUMMULINA, D'Orbigny. (Subgenus.)

Nummulites acuta, Sow.; *scabra*, Lam. Equilateral, discoidal, wavy; centre rather abruptly prominent, margin thin, acute; surface presenting a subgranular, reticulated structure, the interstices of which tend to a spiral arrangement towards the circumference. Internally consisting of a thin central plane of chambers arranged in a spiral form, with layers of compressed ones above and below it. Whorls numerous. Chambers three times as long as the whorl is broad. Septa straight, or but slightly reflected; each chamber divided into three or more reticulate divisions by subsepta, which structure, extending from the circumference to the central prominence, gives the surface the reticulated appearance mentioned; each interstice corresponding to a compressed cell, which is the external extremity of a columnar pile extending down, more or less regularly, to the central plane. Diameter

* For further observations on the structure of *Alveolina*, see Ann. and Mag. Nat. Hist. vol. xiv. p. 99.—1854.

of largest specimens 8-12ths of an inch; thickness in the centre 3-10ths; but this varies; its chief character is its reticulated surface (figs. 21, 22).

Loc. Sinde, Arabia.

Obs. The reticulated structure on the surface, while it characterizes this subgenus of *Nummulina*, also allies it strongly to *Orbitoides*. Another character which distinguishes *N. acuta* from the foregoing species is the greater length of the chamber, being in the direction of the spire, instead of across it, and its subdivision into reticulate ones, which, with the thinness of the central plane, implies a commencing disappearance, or imperfect state, of the latter generally; it is also more abruptly prominent in the centre, and thinner and more expanded in the margin; all of which, while it separates *N. acuta* from the *Nummulites* of the first class, tends towards the structure of *Orbitoides*, in which the chambers of the central plane are arranged subspirally. The lines, too, which are seen descending, in this as well as in other discoidal Foraminifera, to the central plane, are but the opaque matter filling up the interstices between the reticulate chambers; and in the midst of which are situated the interseptal vessels, which pass down to the central plane, and ramify throughout the shell.

On a re-examination of the portion of arenaceous nummulitic limestone from Muskat, which the late Captain Newbold found there *in situ*, and presented to the Asiatic Society of Bombay, I find, by sections of a part of it, that the nummulites of which it is chiefly composed are also *N. acuta*, and not *N. obtusa*, Sow, as I had before, on a superficial observation, stated. The mass is chiefly composed of small specimens of this species, but they vary in size up to 15-24ths of an inch, which is very nearly that of the larger individuals in Sinde.

N. Garansensis (figs. 19, 20), (Joly et Leymerie, Mém. sur les Nummulites, pl. i. fig. 9, and D'Archiac and J. Haime, pl. iii. figs. 6, 7), I have not seen in Sinde, but it abounds in one part of the nummulitic rocks of the island of Masira, on the SE. coast of Arabia. It is also subgranular on the surface, and presents the reticulated structure of the species just described, but with a tendency to radiation in its lines, which approximates it to the nummulites of the first class or simple chambered, and therefore its place here should precede *N. acuta*. Its diameter is 9-24ths of an inch, and its thickness 3-24ths of an inch. Accompanying it were myriads of a smaller nummulite of the same structure, but relatively much thicker, being semi-globular; and until I saw a figure of *N. Lamarcki*, D'Archiac, and J. Haime, in Fos. Num. de l'Inde, pl. iv. fig. 14, I thought, from the different sizes of *N. Garansensis* present, that I could perceive a gradual change in form and size, from one into the other. Be this as it may, the small globular num-

mulite closely resembles *N. Lamarcki*, and is of the same size as the figure to which I have referred.

I hardly think that I can be wrong in my identification of this reticulated nummulite of Masira with *N. Garansensis*, as figured by the authors of the Foss. de l'Inde, *loc. cit.;* at the same time the reticulated structure of the adult specimens from Masira, when compared with that of an adult specimen of *N. acuta* from Sinde and Muskat, is found to be so much more open, that I should be inclined to change the position of these two species, placing the former among the *Sub-reticulatæ*, and the latter among the *Reticulatæ* of D'Archiac and J. Haime. The magnified view of the reticulated structure of *N. Garansensis*, given by the authors just mentioned, fig. 7 *f*, being one of "30 diameters," could not have been taken from one much more than a third of the diameter of the adult specimen given at fig. 6, and, therefore, must have been a young one. Now, the small specimens of Masira, which I have stated to resemble *N. Lamarcki*, also give this view, and so indeed does the central part of the adult individuals; but if the surface of the latter be compared with that of the adult specimens of *N. acuta seu scabra* from Sinde or Muskat, the reticulated structure will be found to be much more open than either.

CYCLOSTEGUES, D'Orbigny.

Orbitoides, D'Orb.

1. *Lycophris dispansus*, Sowerby. (Grant's Geology of Cutch, *loc. cit.*) Discoidal, wavy, more or less equilateral, centre abruptly prominent, margin expanded, and excessively thin and fragile at the edge; surface subgranular or tuberculated, especially over the central prominences, tubercles round, irregular in size and shape, united together by stellate lines. Internally presenting an extremely thin plane of quadrangular chambers, compressed vertically, oblong, and arranged subspirally, with their long axis in the direction of the horizontal diameter of the shell. Compressed chambers above and below the central plane, arranged in successive layers, like those of nummulites, and more or less over each other, so as to form columns, which radiate more or less regularly from the central plane to the periphery, and end in the tubercles before mentioned. Diameter of largest specimens half an inch, thickness in the centre $\frac{2}{12}$ inch (figs. 23—29).

Loc. Sinde, Cutch, and Arabia.

Obs. I have already stated that the chambers of the central plane (fig. 24) of this genus commence from a central cell. This cell is spheroidal or elliptical, and perhaps a little larger than the generality of those which succeed it; the next formed is semilunar, and then comes a pear-shaped chamber or two; after which, the rest, that are in contact

with the central cell, are more or less polygonal. From each of these chambers comes off a line of others in a spiral form, which, diminishing abruptly in breadth, terminates upon the back of the preceding one, the first being the shortest; to this succeeds another series of lines or rows, terminating in like manner, but of wider extension; and so on successively, until the plane, as before stated, appears to be formed of concentric circles. Sowerby's account and figures of the external and internal structure of this fossil (*loc. cit.*) accord with my own observations; but Dr. Carpenter (Quart. Journ. Geol. Soc. *loc. cit.*), I think, has been misled in considering the pillars of Sowerby "nothing more than the opaque matter filling the perforations"; since by a proper section these columns are seen, as before stated, to be the piles of compressed cells (fig. 29), as they ascend from the central plane surrounded by the "opaque matter" to the periphery. It is in this "opaque matter" that Dr. Carpenter's "perforations" are situated, that is, in the interseptal or intercellular spaces, which it partially fills; his perforations being the orifices of the interseptal vessels described in the structure of the shell of *Operculina Arabica* (*loc. cit.*).

In this species of *Orbitoides* we have the "stellate lines" uniting, or, as it were, supporting the columns of the cells. They consist of bars or vertical septa of opaque matter extending from one column to another, in straight lines, but diminishing in thickness towards the central plane, where they become faint and at last disappear altogether. They form the only distinguishing character between this species and *Orbitoides Prattii* (see illustrations to Dr. Carpenter's paper, *loc. cit.*); yet I am pretty sure that I have seen them in a section of the latter, near the central plane (where of course they were not present on the surface), just as they are represented in fig. 14 *b* of Dr. Carpenter's illustrations, which this author regards as a feature of an undescribed species. Hence I am inclined to the opinion that *Lycophris dispansus* and *Orbitoides Prattii* are but varieties of the same fossil.

I should also here mention, that when the central plane of *Lycophris dispansus* is ground down to an extreme thinness, an interseptal space appears between the septa and an opaque line in the centre of it, indicative of the former existence of an interseptal vessel there, as in *Operculina* and *Nummulina*: this is also seen in Dr. Carpenter's illustrations (fig. 34).

2. *Lycophris ephippium*, Sowerby. (*Loc. cit.*)

Loc. Cutch.

Obs. Of this fossil Mr. Sowerby states; "These two fossils [*Lycophris dispansus* and *L. ephippium*] may possibly be different stages of growth of the same species," which seems to me very probable.

3. *Orbitoides Prattii.*

Loc. Sinde, Cutch, Arabia.

Obs. I have just stated the reasons which induce me to think that this is merely a variety of *Lycophris dispansus*.

ORBITOLITES, D'Orbigny.

1. *Orbitolites Mantelli*, H. J. C.; *Nummulites Mantelli*, Morton (Quart. Journ. Geol. Soc. vol. iv. p. 12); *Orbitoides Mantelli*, D'Orbigny (*ib.*). Discoidal, wavy, equilateral or inequilateral; centre abruptly prominent on one or both sides, margin more or less expanded, very thin, plane or wavy, more or less obtuse at the edge; surface smooth, subgranular or tuberculated, especially over the prominent portions of the centre; tubercles minute, round, irregular in size and shape. Internally presenting a central plane, thin at the centre, thick at the circumference, composed of spheroidal or elongated cells, small in the centre, large at the circumference, placed in rows which appear to have a concentric arrangement, but this is indeterminable; cells alternate in adjoining rows. Compressed chambers above and below the central plane, arranged in successive layers, like those of *Orbitoides* and *Nummulina*, more or less over each other, so as to form columns which radiate from the central plane to the periphery, where they end in the granulations or tubercles mentioned. Diameter of largest specimens half an inch, thickness very variable (figs. 30, 31).

Figs. 32, 33, 34 appear to be merely varieties in form of the same species.

Loc. Sinde, Arabia.

Obs. This fossil, though at first sight almost identical with *Orbitoides*, is nevertheless, on minute examination, strikingly different. 1st, it is for the most part inequilateral, which at least is the opposite with *Lycophris dispansus;* its surface also is smoother, from the granulations being more minute. 2nd, the central plane is thin in the centre and thick at the circumference; in *Orbitoides* it is extremely and uniformly thin throughout. 3rd, it is composed of a plurality of layers of spheroidal or elongated cells (figs. 36, 37); in *Orbitoides* it consists of a single layer of quadrangular cells (fig. 27). 4th, the cells are very minute and confusedly arranged in the centre; in *Orbitoides* they are as large in the centre as at any other part, and distinctly arranged. All this, while it tends to separate *Orbitoides Mantelli*, D'Orb., from *Lycophris dispansus*, which is a type of the genus *Orbitoides*, approximates it just as much more to *Orbitolites;* hence my reasons for changing its name.

The subgranular or tuberculated form which this species, as well as *Lycophris dispansus*, presents externally, arises from the extremities of the columns of compressed cells projecting above the surface, increased sometimes, probably, by the intercellular substance having been worn or dissolved away; but this is not the case towards the circumference

on account of the columns being shorter, more vertical, and therefore nearer together, which, of course, renders the intercellular space smaller.

The septa seen in a vertical section of the central plane consist of opaque matter, which surrounds the columns, and as the latter end more or less in pointed extremities upon an imaginary central plane, we often see those of the opposite side interknitting with them, and the chambers of the centre of the plane assuming a triangular shape (fig. 39); sometimes they are quadrangular, and the septa continuous across the plane (fig. 38); at others they are oblong vertically, and curved a little outwards, like the septa seen in a vertical section of the central plane of nummulites, which is their common form towards the circumference (fig. 36); while, just as often, the central plane is composed of two or three layers of spheroidal cells entire (fig. 37); from which I am inclined to infer, that where the other forms appear, it is merely from the cells running into each other vertically, and their parietes in this direction disappearing partially or altogether. In examining a vertical section of this plane, we frequently observe that every other space is a septum, and not a cell: this is owing to the cells being arranged alternately in adjoining rows.

2. *Orbitolites* —— ? Equilateral or inequilateral, discoidal, patulous, more or less wavy, gradually diminishing in thickness from the centre, which projects a little above the general surface, to the margin, which is thin, though more or less obtuse at the edge. In other respects the structure of this is the same as that of the last species described. Diameter of largest specimens, 2 inches; thickness, 3-24ths of an inch (figs. 40, 41).

Loc. Sinde. Sparsely scattered in a bed of *N. acuta*, Sow.

Obs. The great points of difference between this and the last species are, that it is not abruptly prominent in the centre, and diminishes gradually to the margin. It also attains a far larger size; and, as Dr. Carpenter has remarked of *Orbitoides* (Geol. Tr. *loc. cit.*), sometimes "seems, instead of being a circumscribed disc," to have spread itself irregularly in every direction, unless this thalloid form be a different species. From its frequent deep, patulous and wavy form, too, the horizontal sections of this orbitolite in the matrix in which it may be imbedded often indicate a stellate, or other complex figure, which, however, is not the case; for, with the exception of the foliaceous expansion mentioned, it seems almost always to be discoidal. It is sometimes thicker on one side than the other, like the last species, but tends more to a horizontal than a vertical development, and therefore more nearly approaches *Cyclolina* in this respect, which is altogether discal, and without any incrustation on either side, being representative of hardly more than the central plane of this and the last species.

ORBITOLINA, D'Orbigny.

Orbitolina patula, H. J. C. More or less conical and patulous; external surface smooth and marked with concentric, circular elevations, internal surface rough and marked with ridges radiating from the centre; external surface presenting concentric, circular, white lines in the structure, between which, towards the circumference, straight, intervening, septal divisions may be observed like those of the central plane in *Orbitoides;* internal surface presenting a reticulated cellular structure.

Loc. South-east coast of Arabia.

Obs. As yet I have seen none of these fossils from Sinde. The principal part of them are below the 3-12ths of an inch in diameter; at first I mistook them for *Orbitolites*, with which, if not minutely examined, they are easily confounded. They are distinguished from *Orbitolites* by the concentric lines on the smooth and the radiated ones on the rough surface; and from the next genus, viz. *Cyclolina*, by the latter. At the same time larger species occur among them very like *Cyclolina pedunculata*, which also has a tendency to assume this conical patulous form.

CYCLOLINA, D'Orbigny.

1. *Cyclolina pedunculata*, H. J. C. Inequilateral, discoidal, smooth, thin in the centre, with a small papillary eminence on one side; thick at the margin; presenting concentric circles on the surface, alternately raised and depressed, with cells arranged circularly, which are hardly visible to the naked eye (fig. 42). Cells small in the centre, enlarging towards the circumference, spheroidal interiorly, elongated at the surface (fig. 44), arranged in circular rows, alternate in each row. Diameter of largest specimens, 10-12ths of an inch; thickness at the margin, 1-48th of an inch (pl. xxii. figs. 42, 43).

Loc. Sinde, on the Buran river near Jerruk.

Obs. This is, as it were, nothing but the central plane of *Orbitolites;* that is, its development rests here, there being no incrustation on either side, and no compressed cells above or below the disc. I have called it "*pedunculata*" from the little papillary eminence in the centre on one side, this being constant in the few specimens I possess. A similar species abounds in the white limestone of Arabia, also with *Alveolina*, as in Sinde, and therefore in both instances, if D'Orbigny is right in confining this fossil to the cretaceous series, this limestone must belong to this geological period. On the SE. coast of Arabia, it is found in the white limestone of the summit of the series, and in coloured strata more than 2,000 feet below, accompanying the Echinodermata figured by D'Orbigny as typical of his Cénomanien Division (Cours Elémentaire de Paléon. et Géologie Strat. vol. ii. pp. 647, 648).

Cyclolina Arabica, H. J. C. This species chiefly differs from the foregoing in the abrupt, round thickening of the border close to the margin, and in its superior size; the additional substance which gives rise to this kind of rim is confined to the upper or concave surface. Breadth $1\frac{1}{12}$ inch, thickness of the border $\frac{1}{12}$ inch.

Loc. White limestone series of the south-east coast of Arabia, in company with *Alveolina sphæroidea.*

Obs. The above description is taken from a single specimen, which, having its convex or under surface imbedded, prevents me from seeing if it be pedunculated or not.

Thus we have passed, in description, from the simple nautiloid form of *Operculina*, in which the spire and septa are all visible exteriorly, to *Assilina*, where they are more or less obscured in the centre; thence to *Nummulina*, where there is an addition of compressed chambers on each side the central plane, expanding above and below into the globular form of *N. obtusa;* and elongating in *Alveolina*. Returning to the subgenus of *Nummulina*, which presents the "reticulated structure" above and below the central plane, we have passed on to *Orbitoides*, where the characteristic spiro-central plane of the nautiloid forms of Foraminifera is beginning to disappear, and then to *Orbitolites*, where it is entirely lost; ending with *Cyclolina*, which bears the same relation, in the simplicity of its structure to *Orbitolites*, that *Operculina* bears to *Nummulina*.

Explanation of Plate XXIII.

Fig. 1. *Operculina inæquilateralis* (No. 1). 2. Vertical section of ditto.

Fig. 3. *O. Tattaensis* (No. 2). 4 Vertical section of ditto.

Fig. 5. *Assilina irregularis* (No. 1). 6. Vertical section of ditto.

Fig. 7. *Nummulites exponens* (No. 2). 8. Vertical section of ditto.

Fig. 9. *Nummulites Carteri* (No. 1). 10. Vertical section of ditto.

Fig. 11. *N. millecaput ?* (No. 2). 12. Vertical section of ditto.

Fig. 13. *N. obtusa*, Sowerby (No. 3). 14. Vertical section of ditto.

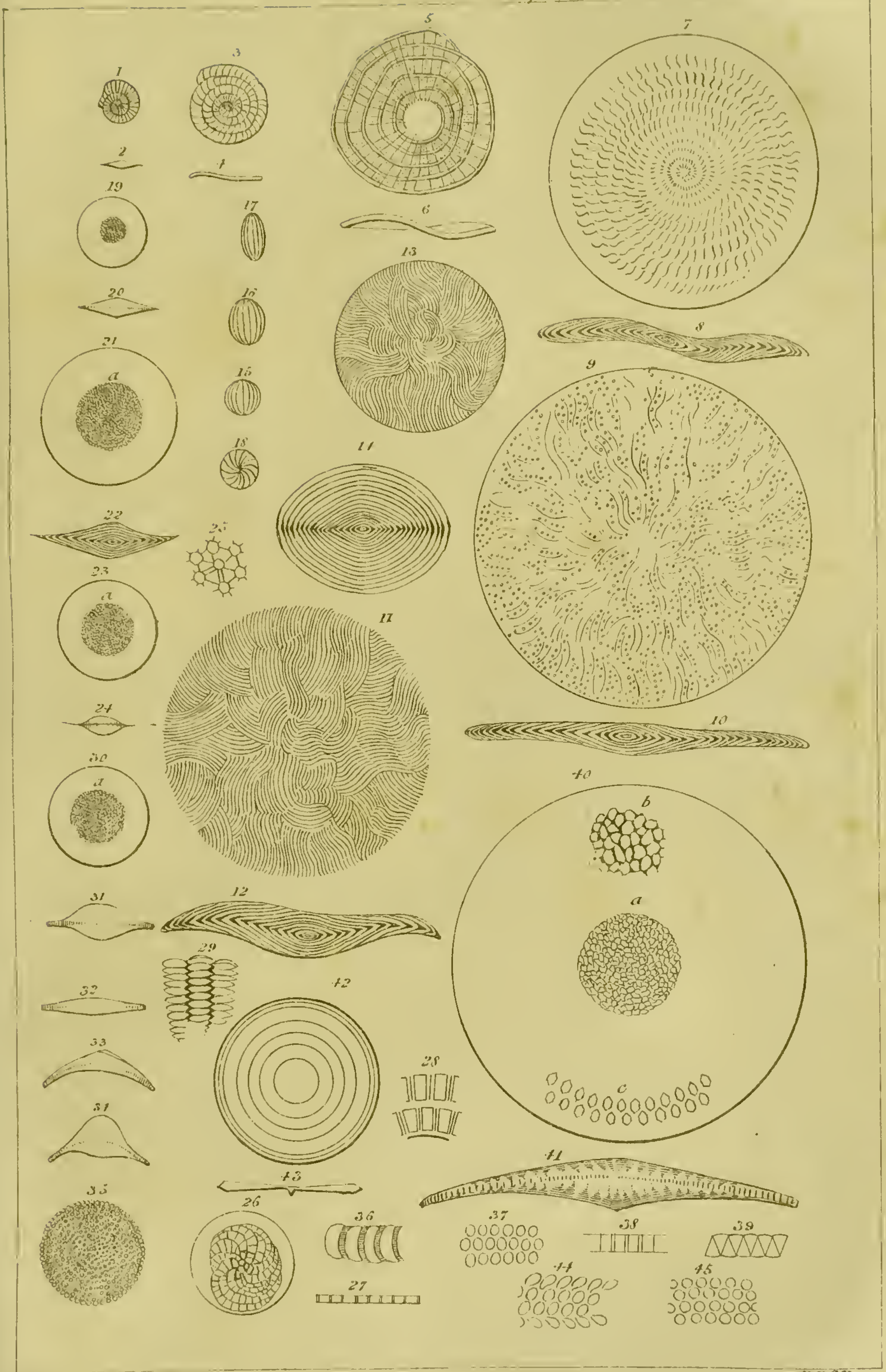
Fig. 15. *Melonites sphærica*, Lamarck (No. 1). 16. *M. sphæroidea*, id. (No. 2). 17. *Fasciolites elliptica*, Parkinson (No. 3). 18. Arrangement of the septal lines at the apex in the last three species.

Fig. 19. *Nummulites Garansensis*. 20. Vertical section of ditto.

Fig. 21. *Nummulites scabra*, Lamarck (No. 4): *a*, magnified view of reticulated structure on the surface. 22. Vertical section of ditto.

Fig. 23. *Lycophris dispansus*, Sowerby (No. 1): *a*, magnified view of reticulated structure on the surface. 24. Vertical section of ditto. 25. Stellate arrangement of tubercles, magnified. 26. Central part of central plane of chambers, magnified. 27. Portion of vertical section of ditto, ditto. 28. Magnified view of septa, showing interseptal spaces and remains of interseptal vessel? 29. Vertical columns of cells ending in tubercles, magnified.

Fig. 30. *Orbitolites Mantelli* (No. 1): *a*, magnified view of reticulated structure of the surface. 31. Vertical section of ditto. 32, 33, 34. Vertical sections of varieties.



H. I. C. fec.

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Fig. 35. *Orbitolites Mantelli,* central plane of, magnified. 36. Vertical section of elongated cells of ditto. 37. Vertical section where the cells are entire, and have not run into each other. 38. Vertical section of central part of central plane where the chambers are quadrangular. 39. Ditto where the internal ends of the columns interlace with each other.

Fig. 40. *Orbitolites* —— ? (No. 2) : *a*, magnified view of surface, showing reticulated structure ; *b*, the same still more magnified ; *c*, arrangement of the cells of the central plane towards the circumference. 41. Vertical section of ditto.

Fig. 42. *Cyclolina pedunculata* (No. 1). 43. Vertical section of ditto. 44. Arrangement and form of cells in vertical section of ditto. 45. Ditto on the surface.

Memoir on the Geology of the South-east Coast of Arabia. By H. J. Carter, Esq., Assistant Surgeon H.C.S. Bombay, formerly Surgeon of the H.C. Surveying Brig "Palinurus." [With a Map, Sketch, and Sections.]*

[Presented October 1851.]

The information from which the following memoir has been compiled was chiefly obtained during the late Surveys of the South-east Coast of Arabia by Captain Sanders† and Lieutenant Grieve, I.N. Much has been contributed by Lieutenant Grieve, who latterly had sole charge of the Survey, through specimens and descriptions of parts which I had not an opportunity of examining; and the geology of the Curiyah Muriyah Islands is extracted from the late Dr. Hulton's interesting account of them, taken during the time they were surveyed by Captain Haines, I.N., now Political Agent at Aden.

I shall arrange this matter under the following heads, viz. 1st, a short geographical description of the coast ;‡ 2nd, geological description of it so far as our information extends ; 3rd, a summary of this information ; and 4th, a tabular view of the strata that have been observed.

Although I have only mentioned the South-east Coast of Arabia, I shall begin at the Straits of the Persian Gulf and go on from thence to Ras el Hăd, then follow the south-eastern coast and its islands to the Straits of Bāb el Mandeb, and, lastly, crossing over to Berbera, pursue the African Coast from this point, with its islands to Socotra. I have not

* Reprinted, with alterations and additions, from the Journal of the Bombay Branch of the Royal Asiatic Society, vol. iv. p. 21. Jan. 1852.

† It is but due to state, to the memory of this able surveyor and excellent officer, who died at sea near Malta on the 14th August last, that I received the greatest kindness from him during the time I had the good fortune to be under his command.

‡ For a more extended description, see the Journal just mentioned, vol. iii. part 2, p. 224.

much to offer of the former or latter coasts, but what little I have will, I think, be found interesting in connection with the South-east Coast of Arabia.

Geographical Description.—Beginning, then, from Ras Măssăndăm, which is the name of the western side of the Straits of the Persian Gulf,—the mountains which form this promontory have been fretted into innumerable irregularities, and suddenly rise from 400 feet, which is the height of the small island called Măssăndăm, at the extremity of the Cape, to 2,000, then 3,000, and subsequently, as they progress in a semi-circular direction, south-eastward, to 6,000 feet above the level of the sea, which they are at a point some miles inland opposite Măskat; leaving in their course a comparatively flat country between their lower hills and the sea, which is called Bātānă. This flat country extends to within fourteen miles of Măskat, after which the land which is raised up into a confusion of ridges and hills, with scarped precipices, presents an irregular sea-cliff on to the neighbourhood of the "Devil's Gap"; and inland, a succession of elevations which end in the ridge just mentioned. This ridge, which is about forty miles from the sea opposite Măskat, is, as before stated, about 6,000 feet high, and goes by the name of Jibăl Făllah, after which, proceeding southwards, it gradually approaches the coast, and terminates at the "Devil's Gap," of which it forms the northern boundary, where it is 6,228 feet high; * the "Devil's Gap" is the outlet of a great valley, which ramifies up among the mountains of Oman. From its southern boundary another ridge, which attains a height of 4,400 feet† within eight miles of the sea, and descends to the latter in two or three precipitous cliffs, arises and is continued on south-eastwards to Jabăl Jallān, which is about 3,900 feet high ‡ and about twenty miles inland from the south-eastern coast: Jibăl Jallān is the southern extremity of the great mountainous chain of Eastern Arabia. From its eastern side a group of mountains extends towards Ras el Hăd, or the eastern extremity of Arabia, to which we shall come presently, and it subsides in the other directions in low hills.

The eastern extremity of Arabia, commonly called El Hăd, is truncated, and presents a coast facing due east, about twenty miles in extent, with a sea-cliff about 100 feet above the sea, which is the general level of the land here.

Turning this extremity to the south-west, we get no more sea-cliff for a long distance, and, after passing opposite the termination of the great chain to which I have alluded, that is, Jibăl Jallān, the land soon subsides to a general level of from 50 to 100 feet above that of the sea, without any mountains interiorly, or towards the south-west, but presenting a continuity of low undulating hills, of a sandy-looking aspect, and a

* Chart; Lieutenant Grieve. † Idem. ‡ Idem.

light brown colour, as far as the eye can reach. This continues on to opposite the island of Masira, where the mainland sinks to the level of the sea,—the only place on the coast where this occurs unbacked by mountains.

The island of Masira, which is opposite this point, is rocky and mountainous, and in its highest part not more than 600 feet above the level of the sea.

After Masira, the mainland begins to rise again, and a sea-cliff first commences at a Cape called Ras Kābrêt in 19° 57′ N. lat. and 57° 48′ E. long. The land, however, on the western side of the bay, called Ghobăt Hăshish, which is a little to the north of Ras Kābrêt, is 80 feet above the sea,* and goes on increasing in height, until it attains an altitude of 480 feet† at Ras Mărkăs, which is close to Ras Jăzirăh. On account of the coast here running north and south for 100 miles, and therefore obliquely to its general direction, which is NE. and SW., we not only see that the land rises towards the SW., but that it rises also towards the south.

From Ras Jăzirăh, where the cliff, from its height and whiteness, very much resembles that of the south-east of England between the North Foreland and Beachy Head, the coast gradually increases in elevation to 800 feet, which is its height about the centre of Curiyah Muriyah Bay; but as we approach the south-western horn of this bay, its outline and horizontality become disturbed, and suddenly it attains an elevation of 4,000 feet, which it preserves, more or less, on to the Yaffai mountains, at the Straits of Băb el Mandeb.

Opposite Curiyah Muriyah Bay are five small islands, which, in point of size, are hardly more than the tops of so many mountains; they are about twenty miles off shore, and the largest and highest, which is Hăllăniyah, has a point 1,645 feet above the level of the sea. There are also two or three still smaller, much further on towards Aden, viz. opposite Hisn Ghorab, about sixty miles south-west of Makalla. These are all the islands on this coast.

The chief features of the land between Curiyah Muriyah Bay and the Straits of Băb el Mandeb are, that here and there it is more or less tabular in its outline; here and there more or less broken into mountainous peaks; here and there more or less interrupted by ravines; five times by great valleys; and once (in the Bay of El Kămmăr) by a tract of low land forty to fifty miles in breadth, which, running SW. and NE. between the mountainous ridges of which this elevated coast is composed, thus separates them longitudinally as far as the eye can reach.

Throughout, the high land is more or less scarped upon the sea or the maritime plain, and the latter seldom more than ten miles in breadth.

* Lieutenant Grieve. † Idem.

Its colour is for the most part white, particularly where it is weather-worn, but here and there black or brown, where it is confronted by, or mixed with, rocks of an igneous origin.

Having thus given a brief outline of the coast, let us now direct our attention to the rocks of which it is composed.

Geological Description.—Returning to Ras Măssăndăm, which, as before stated, is the western promontory of the Straits of the Persian Gulf, and the northern extremity of the chain of mountains which extends along the North-eastern Coast of Arabia, from the Cape just mentioned to the neighbourhood of Ras el Hăd, we find this promontory, taken generally, to be mountainous, and fretted out into innumerable irregularities, which have given rise to the formation of as many coves, creeks, inlets, islands, islets, and rocks. The extremity, called Ras Măssăndăm, is an island 400 feet high, and the next portion, which is on the shore, about 1,500 feet, while but a few miles further inland the latter rises to 3,000 feet. At sight these mountains appear like basalt, from their black colour, and hence have been described as such by Captains Wellsted and Whitelock, and have always been considered igneous rocks. Pliny calls them the Eblætian Mountains, probably from the Arabic *iblis*, the devil; but latterly this promontory and its islands have been inspected by Lieutenant Constable, of the Indian Navy, who has kindly shown me specimens from them, which prove that they are all composed, not of black basalt, as before suspected, but of jet black and dark grey-black limestone, interstratified and veined with white and pinkish brown calc-spar. The jet black limestone is of a fine compact structure, and breaks with a smooth conchoidal fracture, like lithographic limestone, but the lighter coloured varieties are more coarse, and break with a rough fracture. The calc-spar, which is in strata of eight to ten feet thick, is columnar, or vertical, in its crystallisation, and traversed horizontally by wavy lines, like that of Gibraltar: some of it is of a dazzling whiteness, and of a massive, saccharoid, crystalline structure. I was informed by Lieutenant Constable that the whole of these mountains here are of a similar composition, and they are horizontally stratified, the strata in some places being thinner and more slaty than in others.

Proceeding southwards, this chain of mountains, as I have already stated, curves inland, and leaves a low country in front of it, called Bătănă, which is without sea-cliff, on to a point four miles north of Măskat. It is from this point that my observations commence. To the north of it, as far as the eye can reach from an elevation of 600 feet, I could see nothing but a low shore, shelving up very gradually to the chain of mountains inland, each shelf presenting a scarped surface of a chalky appearance; thus giving a general whiteness to the whole

district, from which I inferred at the time that it was a continuation of the same limestone formation as that of the sea-cliff on which I was standing when I made these remarks.

Subsequent observation, however, on other parts of the coast has led me to consider it of much greater thickness, probably belonging to the Cretaceous Series, as the one about Măskat, to which we now come, and is comparatively thin, will presently be seen to belong to the Nummulitic Series.

In a geographical point of view, Măskat, as we approach it from the sea, is characterized by a group of dark-coloured rocks, whose peaks become more and more visible as we near them, until one, more prominent and larger than the rest, points out the position of the town itself. So soon as this peak is recognized there remains no doubt of the course to be pursued, and presently we find ourselves in a deep narrow bay, a mile long and half a mile broad, running parallel to the coast and opening to the NNW.

Nothing can be more picturesque than this bay, its green water, the dark colour of its rocks, their innumerable peaks, the white towers at the bottom, and the white castles at its entrance ; all of which are so completely hidden from the sea that their existence is hardly known until we are within cross-fire of the two outermost batteries.

These dark rocks occupy an area of about ten miles long and three miles broad, and are chiefly composed of Serpentine (Euphotide, Brong.?), which is limited on the coast and inland, by a yellow coloured limestone formation. Their ridges and summits are sharp and peaked, and seldom exceed 400 feet in height, and their sides and valleys soilless and barren. At their northern part they are mixed with Diorite, and at this point also potstone (steatite) exists, which is sufficiently yielding to allow of its being moulded into shape for pottery.

The Serpentine is, for the most part, of a dark brown colour, and more or less charged with small laminated crystals of *diallage chatoyante.* When taken from a depth it is tough and not easily broken, but on the surface crumbles and breaks into rectangular fragments, the sides of which are more or less coated with green and variegated nephritic serpentine, steatite, or calcareous spar. In some parts it is of a light brown colour and earthy, while in others it is darker, and more compact or crystalline, presenting in the fracture when broken the appearance of dark-coloured bees' wax. It is exactly the same as that of the Lizard Point in Cornwall, with the exception, perhaps, of the presence of green diallage, which, if existing in the Serpentine of Măskat, is of a much duller colour than that in the Serpentine of the Lizard.

Everywhere these Serpentine rocks at their circumference are bounded and overlapped by the yellow limestone formation mentioned, which,

like them, is also barren and contrasts strongly in point of colour, form, and stratification.

A more extended examination of this Serpentine would of course have enabled me to write more about it, but this I was unable to effect, and, had I done so, the character of the rock, its variety of form, structure, and composition, are points now so well known, that such information of the Serpentine of Măskat, if I gave it, would probably be only a repetition of what has already been much better described.

Proceeding southward to the limit of the Serpentine, we find it bounded six miles from Măskat by a head-land named Ras Ghissa, which slopes into the sea, and has lying close to its base a little island about thirty yards square, the geologieal section of which, with that of the Cape as given in the next page, I shall now describe.

Commencing with the Island (Section No. 1 *a*), for reasons which will better appear hereafter, we find its base (*a*) composed of brown Serpentine, like that already described, interspersed with crystals of *diallage chàtoyante*, and intersected in all directions by numerous veins of white quartz (magnesite ?), similar to those which are common to cracked basaltic formations. On this rest, from below upwards, the following strata :—

(*b*) A coarse yellow sandy deposit about three feet in thickness, overlaid by—

(*c*) A bed of pebbles, smoothly rounded by attrition, and frequently measuring a foot and a half in diameter. These pebbles consist of grey, compact, and sometimes variolitic basalt, petrosilex, and quartzite of various colours. I saw no granite, sienite, or even Serpentine amongst them, although I sought for the latter much, and am at a loss to account for its absence, unless, from being softer and more easily decomposable than the rest, it had become disintegrated and had thus disappeared. Certainly one would expect to find in a sediment of pebbles like this a few portions at least of the underlying rock, but my observations did not lead me to this fact, although a more extended search might perhaps have done so.

This, then, comprises the strata of the Island, and I must now state that I have given them first, because those of the Cape called Ras Ghissa, which are hid below and only a few yards off, appear to be a continuation of them; not only on aecount of the material being of the same kind, but from the formation of which this cape is composed resting on the same kind of igneous rocks about the same distance north of Măskat,—as will be evident by a reference to Section No. 2, on the page opposite.

Commencing, then, at the base of the scarp of Ras Ghissa (Sect. No. 1, p. 557), with the lowermost stratum that can there be seen, we find it to present,—

Sections of the Nummulitic Series surrounding and overlying parts of the Serpentine Rocks of Maskat and its neighbourhood north and south.

Section No. 1.—Ras Ghissa.

Strata	Bed
Coarse limestone of a whitish yellow colour, almost wholly composed of the remains of small Foraminifera.	*f.*
Loose silico-calcareous limestone of a pink colour, abounding in small Foraminifera. (*Operculina*)	*e.*
Coarse yellow silico-calcareous limestone, abounding in corals, casts of shells, and cavities of calc-spar.	*d.*
Sandy limestone with Gryphæa; loose yellow sand.	*c.*
Pebble bed	*b.*
Variegated sands.	*a.*

The sea.

Strata	Bed	
Pebble bed of Island.	*c.*	Sec. No. 1 *a*, Island.
Sandy deposit.		
	b.	
Serpentine.	*a.*	

Section No. 2.—Village of Darzit.

Bed	Strata
f.	Coarse limestone of a whitish yellow colour, the upper part of which is almost wholly composed of the remains of minute Foraminifera.
	Coarse compact yellow coralline limestone.
e.	Still coarser silico-calcareous coralline limestone.
	Red argillaceous strata with gypsum, &c.
d.	Coarse yellow silico-calcareous sandstone with shells, veins of gypsum, and cavities of calc-spar.
c.	Coarse sand.
b.	Pebble bed
a.	Greenstone.
	The sea.

N.B.—The dotted lines stand for pebbles.

(*a*) A deposit of beautifully variegated sand (grit), the particles of which increase in size upwards.

(*b*) A bed of dark pebbles about 50 feet thick, smoothly rounded, and consisting of the same kinds as those of the island, but somewhat smaller, seldom exceeding six inches in diameter.

(*c*) A deposit of yellow sand, without pebbles, which, gradually presenting the remnants of a shell or two, and the addition of calcareous matter, at length passes into a coarse yellow siliceous limestone containing the remains of many marine shells, among which the most numerous is a small *Gryphæa* about an inch long.

(*d*) A still more calcareous deposit, yellow and ochry, in which are many cellular cavities filled or lined with calcareous spar, and a great abundance of organic remains; chiefly consisting of corals and the casts of marine shells; also in this is seen again, here and there, a thin line of smooth dark pebbles of the kind already mentioned.

(*e*) A pink calcareous deposit, with still less siliceous sand composed almost exclusively of the remains of delicate polythalamous shells of the genus *Operculina*, D'Orbig., with the remains also of a few *Spatangites*.

(*f*) A coarse, yellow-coloured, compact limestone, about 60 feet thick, forming the uppermost stratum of the Cape, and which, like the foregoing, is almost exclusively composed of the remains of minute polythalamous shells, but in a white, pulverulent state.

Throughout the lower strata of this Cape, black compact, petrosilex-like, basaltic pebbles are scattered here and there, and only disappear altogether at the commencement of the pink stratum just mentioned, wherein the presence of the remains of innumerable delicately formed polythalamous shells points out a time at which the sea had become more settled, and the currents had ceased to bring to this spot any more of the gross material which had preceded their formation.

The fossil remains which fell under my notice during the short time I had to examine these strata consisted of a few univalve and bivalve shells, corals, an abundance of small Foraminifera, and a few Echinodermata, but no Cephalopoda.

Assuming, then, that the sand and pebble-bed of the island is the lowermost deposit of the sands and pebble-beds, &c. of Ras Ghissa, we have the strata of this Cape lying on the Serpentine of the neighbourhood, as already noticed on Diorite at the northern extremity of the igneous rocks.—Thus, then, it consists of, first, a sandy pebbly deposit, without the presence of organic remains; then with the remnants of a shell or two making their appearance, even among the pebbles, the pebbles diminishing in number, and giving place to sand alone; then a slight admixture of calcareous matter, the presence of the remains of

more marine animals; and, finally, a silico-calcareous limestone; this followed by a great increase in the number of fossils; the calcareous matter beginning to predominate; a pink stratum richly charged with small polythalamous shells; and, lastly, a coarse, but almost pure limestone, 60 or more feet in thickness, almost entirely composed of them.

Thus much for the limestone formation, which limits the Serpentine rocks to the south of Măskat.

If we now conceive an irregular line extending from Ras Ghissa to a point about three miles inland from Măskat, and carried out again to meet the sea four miles to the north of this town at a little village called Darzit, and then picture to ourselves the limestone formation just described raised up on the Serpentine in all kinds of positions along this line or arc, with the cord or coast-line of the Serpentine zig-zagged into the greatest irregularities, forming coves and creeks in each of which is a little sandy beach, we shall have some idea of the extent and isolated position of the Serpentine rocks of Măskat, and of the principal physical features of the neighbourhood.

At Darzit the Serpentine is again limited by the limestone formation, with the intervention of Diorite and potstone as before mentioned; the limestone forming the northern ridge of the valley in which this village is situated.

Here it is raised to the height of about 600 feet above the level of the sea, but does not rest on Serpentine as assumed at Ras Ghissa, but on its companion Diorite, a coarse-grained rock composed of crystals of dull green hornblende in a mass of white, grey, or pinkish semicrystalline felspar. The appearance of this rock, which at first sight resembles sienite, varies according to the preponderance of one of its ingredients over the other.

On peaks of such Diorite, then (*a*), rests the limestone formation at this point (See. No. 2, p. 557), and the strata are composed from below upwards as follows:—

(*b*) A bed of pebbles resembling that at Ras Ghissa in almost every particular, but more disturbed, indicating subsequent elevation of the greenstone. This deposit gradually passes into,

(*c*) A coarse sandy stratum (grit), and then into,

(*d*) A silico-calcareous, yellow, coarse sand, more or less compact, presenting numerous traces of marine shells, and intersected by veins of gypsum. Next to this comes,

(*e*) A still more compact and still more calcareous deposit, which is replete with the fossilised remains of marine animals, especially large masses of coral—*Madrephylliœa*, *Madrastrœa*, &c.

Through this passes a remarkably coloured, but narrow series of gypseous, marly, and arenaceous strata. The gypsum hardly exceeds 1½

inch in thickness, and is of a deep amethystine colour, while the other strata present different shades of yellow, blue, and green. This series is about midway between the top and bottom of the scarp. Above it comes,

(*f*) A coarse, whitish fawn-coloured, compact limestone, presenting below the remains of many marine shells and corals, and towards its upper part hardly anything beyond those of minute polythalamous shells.

I regret much that I could not examine this limestone more particularly, for it comprises, like that of Ras Ghissa, nearly the upper half of the formation ; but I was prevented from doing so at the place where I visited it, by its being so perpendicularly scarped.

Thus, we observe that the limestone formation limiting the group of igneous rocks at Măskat, both north and south, commences with a deposit of the same kind of pebbles, lying in both instances on the igneous rocks of the locality ; passing into a sandy grit ; then into a silico-calcareous deposit ; then presenting the remains of marine animals; these increasing in number with the calcareous matter ; a gradual cessation of the deposition of coarse material, the increasing purity of the limestone interrupted in each instance by a pink-coloured deposit, that at Ras Ghissa chiefly consisting of the remains of foraminifera, and that at Darzit of a thin series of gypseous, marly, and arenaceous strata, ending above with a compact yellowish or fawn-coloured limestone, at both places almost entirely composed of the accumulated remains of polythalamous shells.

I saw no gypsum at Ras Ghissa, it is true, but it must be remembered that these are the notes of hurried visits, and, therefore, I am by no means certain that there was none in a similar position to that in which it is found at Darzit; but the cellular, cavernous cavities were there filled or lined with calcareous spar as at Darzit.

From so many points of resemblance, then, we can hardly doubt that the limestone formation, both north and south of Măskat, is the same, and, therefore, that the group of Serpentine rocks here is also surrounded and overlapped by it inland. We are also certain of the geological age of this formation, of which I remained uncertain until Captain Newbold showed me a mass of nummulites which he had found in it *in situ*, near Măskat, and afterwards deposited in the Museum of the Asiatic Society of Bombay.

The stratum from which this specimen was taken, Captain Newbold states in his list* to overlie the conglomerate (that is, the pebbly deposit I have mentioned) behind Măskat. I had not the good fortune myself to see the stratum, but the specimen presented by Captain Newbold is so

* Journal Bombay Br. Roy. Asiatic Society, vol. iii. part 1, p. 27, Specimen 7.

genuine and his authority so good, that there can no longer be any doubt as to the fact any more than the designation that should now be given to this series. In my cursory examination of these strata I had failed to meet with this deposit, and therefore the limestone formation in the vicinity of Măskat was an enigma to me; but it is no longer so now, and must be laid down as belonging to the Nummulitic Series.

The following are descriptions of the fossils found in this formation :—

FORAMINIFERA.

Nummulites scabra, Lamarck; *acuta*, Sowerby. (Grant's Geol. Cutch. Geol. Trans. 4to, vol. vi. pl. xxiv. fig. 13.) *Loc.*—Măskat.

Obs. The specimen containing these nummulites is the one to which I have just alluded. I cannot say from what part of the series it came, but the fact is sufficient to prove that this formation, if not the whole, is a part of the Nummulitic Series. At first I called it *N. obtusa*, Sowerby, but, since that, I have examined it by sections, and find it to be his *N. acuta*. (See p. 544, this vol.)

Operculina inæquilateralis, H. J. C.* Inequilateral, oval or discoidal, thin, horizontal or wavy; centre slightly prominent, margin thickened, rounded, cord-like. Spire more or less irregular, more apparent on one side than the other, consisting of three whorls, concave on one side, flat on the other, increasing rapidly from a central cell. Chambers numerous, narrow, slighty reflected. Septa reflected, more apparent one side than the other. Diameter of largest specimens 5-24ths of an inch.

Loc. Măskat.

Obs. This species abounds in the silico-calcareous sandy part of the formation of Măskat, just before the latter passes into compact limestone.

ECHINODERMATA.

Spatangus.—*Species?* Subovate. Length $1\frac{4}{12}$ inch, breadth $1\frac{2}{12}$ inch, thickness $\frac{10}{12}$ inch. Notched anteriorly, truncated, and overhanging posteriorly, with the vent in the upper part, from which a ridge extends on to the genital pores. Ambulacra four, sunk in grooves, slightly truncated, the two posterior shorter than the two anterior ones. Base subcarinated in the centre, mouth bilabiate, near the margin. *Loc.*—Măskat.

Obs. From the pink stratum which abounds with the *Operculina* above mentioned.

ZOOPHYTA.

Caryophyllia.—*C. cornigera?* Lam. *Loc.*—Măskat.

Obs. This species is very like *C. Anthophyllum* (Lam. et Ellis, tab. 29), but has rounded extremities and contracted stellæ at the ends of them.

Agarica, Meandrina, Astrea, and Scyphia (Goldf.).

* Ann. and Mag. Nat Hist. vol. ii. p. 167, pl. vii. figs. 1 and 2, 1853; and this Vol. p. 539.

CONCHIFERA.

Gryphæa.—*Species ?* (Cast of lower valve, imperfect.) Length $1\frac{6}{12}$ inch, breadth $1\frac{3}{12}$ inch. Deeply carinated ; irregular, wavy, or lobed towards the circumference, and expanded, particularly towards the right side. *Loc.*—Lower sandy part of aqueous strata, Măskat.

Gryphæa.—2nd *Species ?* (Lower valve, incomplete.) Length $1\frac{3}{12}$ inch, breadth $\frac{3}{4}$ inch. Deeply carinated, expanded, plane towards the circumference ; smooth externally, presenting concentric striæ ; uncinated, like *O. Uncinata*, Desh. (Coq. Fos. Envir. de Paris, tome 1, tab. 18, figs. 7—11.) *Loc.*—Măskat. *Obs.*—This and the foregoing species abound together, and are more or less ostreiform.

GASTEROPODA.

Natica.—*Species ?* (Cast, incomplete.) About 2 inches long. First and second whorls depressed. *Loc.*—Măskat. *Obs.*—Imbedded in a yellow calcareous stratum, or granular deposit, consisting of minute Foraminifera.

From Ras Ghissa this limestone formation is continued on for thirty or more miles in an extremely broken condition, being raised up in ridges one after another, having their white fractured surfaces towards the north-east, and their original surfaces sloping in the opposite direction ; consequently, the sea-cliff which faces them is also extremely irregular. After the distance mentioned, the formation loses its broken character, and passes into round and isolated hills, which are terminated by the great inland ridge approaching the sea to form the northern boundary of the "Devil's Gap," which, as before stated, is 6,223 feet above its level. Here there is a break, and no cliff for a few miles, until the ridge, which forms the opposite or southern boundary of the opening of the valley, commences, and this, attaining a height of 4,400 feet not above eight miles from the sea, presents, as may be conceived, an immense mural surface in this direction.

From the summit of the ridge here, which is called Jibal Jābăr, the land descends to the sea in two or three gigantic cliffs, and is thus scarped the whole way to the town of Soor, where the coast line, turning still more to the east, leaves the scarped ridge to pursue its course southwards, and terminate in the mountains of Jallan. Lieutenant Grieve states (Priv. MS.) that near a deep narrow valley called Wadi Shāb, about thirty miles NW. by W. of Ras el Hăd, "the Jibal Beni Jābăr rise abruptly from the sea to a height of about 3,000 feet." Rock-specimens from this valley show that this mountainous ridge is composed of limestone, like that of the other parts of the coast. Its scarped bared surface presents a horizontal stratification, and a general light brick-red colour, which is the prevailing tint of the limestone formation throughout

the whole coast of Southern Arabia. This arises from the presence of more or less red argillaceous earth, which, existing in the cavities of the rock, and about the organic remains, becomes liberated as the rock weathers, and thus, spreading over the white limestone, gives it the tint mentioned; in some parts it has entered into the composition of the rock itself, which then is of a cream colour. Opposite the scarped surface of Jibal Jābăr there are no soundings half a mile off shore, and this is invariably the case on this and the south-eastern coast, where the land rises abruptly from the sea,—wherever it is highest the soundings are deepest, and *vice versâ*.

From the town of Soor to Ras el Hăd, the coast presents a sea-cliff of about 70 feet high, with land rising inshore to 200 feet, but sinking gradually towards the eastward to the level of the sea, which it attains at Ras el Hăd. It also presents several remarkable irregularities which have evidently been occasioned by subterraneous influence.

Lieutenant Grieve mentions a singular pit on the top of the cliffs two miles east of Soor, which is 80 yards in diameter and 60 feet deep; and after this come two other similar, but much more extensive depressions, viz. the Khors or Lagoons of Jărāmah and Hăjar. The former, entered by a narrow channel from the sea, is three miles long and two broad, with sides of 50 to 70 feet high, and water ten fathoms deep, making in all a depth of 110 to 130 feet below the level of the surrounding land. Khor Hăjar, which follows this, is not more than half the size, and much more shallow, but the same kind of depression.

Rock-specimens from the top of the cliffs about two miles from Soor, near the great "pit," which were kindly sent me by Lieutenant Grieve, show that they are composed of a fine white saccharoid limestone, which has undergone minute fracture, and has had its fissures filled up again by a red coloured cement, probably of the same composition as the parent rock, with some ferruginous infiltration from above. Such a brecciated state is frequently seen on the south-eastern coast, and in all probability has been caused by the shock of some subterraneous explosion or upheaval. At the same time, I have noticed that such rocks are more or less magnesian: the one just mentioned, on a rough analysis, yields about 12·18 per cent. of magnesia, and hardly effervesces at all with acids before it is pulverized; its sp. gr. is 2·72. The specimens from the lower strata of the same cliffs show that they have not been fractured in the same manner, though of the same composition and structure. I think I have also noticed on this coast that the upper strata are those which are most comminutely fractured, while the lower ones are less so or have escaped it altogether.

The rock-specimens from the sides of Khor Jărāmah are of a coarser structure; and when we arrive at Khor Hăjar, where the cliffs sink to

the level of the sea, and are lost under the sand of the plain, there we find them composed of a limestone conglomerate, consisting of pebbles of the older formations, and shells, cemented together by a red calcareous sand, in which there are minute particles of igneous rocks. In some parts, this cement exists as a rock by itself, without the grosser portions, and appears to belong to a loose Miliolitic Formation, which we shall find by-and-bye to prevail throughout the south-eastern coast.

At Ras el Hăd, which is a sandy cape, we have a plain of two or three miles square, connected on its western side with the Khor last mentioned, and on its eastern side forming the northern point of that short piece of coast which, running north and south for twenty miles, terminates the eastern extremity of Arabia. This short eastern face presents a uniform limestone cliff 100 feet high, and of a light yellowish colour, with horizontal strata. Specimens from it show that it is composed above of a compact yellow limestone, breaking with a subconchoidal, uneven fracture, almost identical with that from the cliffs of Kurachi opposite; also of strata of the same kind of material and structure, containing abundance of small Foraminifera; and a stratum of whitish saccharoid limestone, like that mentioned at the base of the cliffs two miles east of Soor; while another specimen from these cliffs shows that there is a stratum of the kind last alluded to, which contains a considerable quantity of hyaline quartz, in minute grains, indeed an arenaceous limestone; it resembles the fine silico-calcareous strata of the limestone formation at Măskat. This is probably the Nummulitic Series of this part passing down into gravel, as at Măskat.

Turning Ras el Khubba, which is the southern extremity of this short facet, we come upon the south-east coast of Arabia, and from this point lose all sea-cliff for upwards of 180 miles; the coast now generally runs NE. and SW., and presents nothing but a sandy shore, which I will more particularly describe.

The first part worthy of notice on proceeding along this coast is a little cape called Ras Rues, which consists of a few hillocks about twelve feet high; this is about three miles from Ras el Khubba. These hillocks are composed of a recent conglomerate, the grosser parts of which are held together by a dirty-looking silico-calcareous sea-sand, and though exceedingly insignificant in appearance, nevertheless they are interesting in a geological point of view, inasmuch as they contain pebbles of all the rocks probably in the neighbourhood. These pebbles consist of diorites, basalt, quartzite, jasper, and portions of the older cretaceous (?) limestone formation, all smoothly rounded by attrition.

After leaving this cape, and passing along the coast, we arrive opposite the mountains of Jallān, which I have already stated to be the termination southward of the great chain on this side of Arabia. They

are about twenty miles inland from the south-east coast, and the highest is about 3,900 feet above the sea. On every side, viz. towards Ras el Hăd on the east, and the Desert of Akhāf on the west, as well as towards the south-eastern coast, they, like other mountainous terminations, subside more or less gradually, and more or less irregularly, to the general level of the surrounding country. This, towards Ras el Hăd, or the eastern extremity of Arabia, is in coin-shaped mountains, which offer beautiful scarps for the geologist, and are easy of access, towards the south, in low conical or dome-shaped hills of a brown sandy aspect, mixed with dark peaks, probably of igneous matter, such as we shall see a little further on; while towards the west the subsidence is more gradual and regular, to hills of about 200 feet high. Mr. Cole, of the Indian Navy, who travelled from Laskhara, a town on the coast just here, to Măskat, along the western side of these mountains, kindly sent me specimens from the hills near Bădiyah, which town is in the same parallel of latitude as the highest of the Jallān mountains. These specimens show that the same kind of black limestone exists there as that which Lieutenant Constable brought me from Ras Măssăndăm; also pieces of fine compact grey lithographic limestone; and of fine argillaceous slate, of blue and black colours. Hence we may infer that the black limestone forms part of the mountains of Oman, both north and south, but whether continuous or isolated, remains for future observation to determine.

Returning to Ras el Hăd we find that, some distance after the subsidence of the mountainous chain has taken place in this direction and the land has assumed a general level of from 100 to 200 feet above the sea, two mountains, close together, and of equal height, being about 855 feet above the plain, stand prominently before us. These, which are called Jibal Săffān, are close to the cliff of the eastern extremity of Arabia, and of course isolated for some distance from any other mountains. They are, therefore, very remarkable, from their situation, and, being coin-shaped and presenting their fractured surfaces towards the west, they also form a fine section, which is easily attainable so far as it goes, of the strata at this point. The sea-cliff, as I have before stated, is only 100 feet high.

From Ras Rues onward we have no cliff, and nothing on the land remarkable, beyond the low, brown, sandy-looking hills, and isolated dark peaks, dispersed here and there among them, until we arrive at a place called Ras Jibsh, which only differs from the rest of the coast in presenting a few of these dark peaks, that are arranged in a ridge-like form about 100 feet high, made more evident by their being a little above the surrounding country. There are now no longer any mountains to be seen inland, and nothing more than a monotonous extent of

brown sandy-looking mounds, from 50 to 100 feet above the level of the sea, as far as the eye can reach in every direction.

The dark igneous peaks which form the cape called Ras Jibsh are probably only a repetition of what we have before seen among the sandy hills; they are composed of euphotide and diorite, as those at Măskat. The diorite, however, presents larger crystals of hornblende, which occurs here in a diversity of forms: sometimes it seems replaced by the diallage of the dark euphotide, or by bronzite or hypersthene; while the felspar sometimes passes into labradorite, of a bluish grey colour, and presenting minute parallel lines of striæ, which traverse the plane of cleavage. One part of this ridge is composed of a very marked rock, consisting of moderately-sized crystals of black hornblende and grey felspar, in equal proportions, among which is disseminated a small quantity of a beautiful grass-green diallage (?): it is not improbable that the black hornblende itself is but a deeper tint of this colour.

There is also, close to these igneous rocks, but much lower than the tops of them, a mound of dull red jasper, undergoing fragmental disintegration: this is probably a chertified condition of some aqueous strata which have been thus altered by the intrusion of, and brought up with, the igneous rocks.

The immediate neighbourhood consists of the yellow sandy hills I have mentioned, probably limestone, more or less obscured by drift-sand.

Inside the ridge of rocks is a small bay, which now only offers a safe landing for boats, but which is said to have formerly extended a long way further inland behind the ridge mentioned, where there still exists a dry lagoonal depression, about two miles square, and 12 feet above the level of the sea. There is also, on the inner side of the ridge, a modern deposit, the upper margin of which is between 20 and 30 feet above the level of the sea. I have already mentioned one at Ras el Hăd, which is raised at least 12 feet above the level of the sea, also a littoral conglomerate at Ras Rues, the upper part of which is about 12 feet above the sea; and here we have a similar deposit, raised 30 feet above it. This is again the Miliolitic Formation.

From Ras Jibsh south-westwards, the coast presents a still more desolate aspect, if possible, than it did to the eastward of this cape: not a dark mound even now appears to vary the colour of the land, close to the sea, or as far as the eye can reach interiorly; but as we approach Ras Abu Ashrin, which is in 20° 58′ N. lat., and 58° 44′ E. long., the light brown colour of the land ceases, and is succeeded by a tract of white dome-shaped sandhills, from 100 to 200 feet above the level of the sea. These extend inland as far as the eye can reach, and are scarped upon the sea, where their structure is satisfactorily seen. None of these scarps, which correspond to the hills forming part of the

line of coast, are, I think, more than 100 feet high. The formation consists of a sandy-grained rock, which, when minutely examined, is found to be chiefly composed of calcareous particles with a small quantity of hyaline quartz and dark specks, probably hornblende, from the igneous rocks. The latter character is deserving of notice, because, as no dark particles of this kind appear in the older limestone, they serve as a distinguishing mark for this formation when it approaches the older limestone in other respects. So uniform is this deposit in its granular structure, that there is hardly a fossil larger than the grains of which it is composed to be seen in any part of it; it is more or less stratified, and, though loose in structure, sufficiently compact to form a good building stone. The thickness of this formation here can only be ascertained by its cliffs, which at the utmost do not exceed 100 feet. It is so loose on the surface that the upper and exposed part has become disintegrated for some depth, and, assisted by irregular upheavals, the original formation has probably thus been transformed into the dome-shaped mounds which it now presents. In some parts the sand is so subtle that it yields to the lightest weight, while in others it is so caked that it will bear that of a man. At a little distance it has the appearance of mounds of snow. Can these be the "winding sands" which are alluded to in the Khoran, into which the tribe of Ad were driven, and are said to have perished? There can be no doubt that they form the south-eastern part of the Desert of Akhāf, and not far from the borders of it where this tribe were originally located;—and could the gulf of sand at the western extremity of this Desert, in which Baron Wrede found a plummet sink to the length of the line attached to it, viz. 360 feet, be the disintegrated sand of this formation, filling some volcanic depression there? There is no doubt that this deposit forms the lowest part of the seaward boundary of the Desert of Akhāf, and it may also form the lower parts throughout; for from this the Desert extends at first a little inland, and then westward, to within 300 miles of the Red Sea. It was about 150 miles from the south-eastern coast, where the "sand-gulf" mentioned was situated. The Desert itself is also said to be impassable, and nothing would render it more so than an extension of such sandhills as those in the neighbourhood of Ras Abu Ashrin, which I can compare to nothing but a picture that I have seen of drift-mounds of snow in the Arctic regions.

When subjected to a chemico-microscopic analysis, if it may be so termed, the calcareous particles of which this deposit is composed are found to be nothing more than the remains of minute Foraminifera, the tests of which, having become partially dissolved and crystallized, have thus cemented the whole together; while this, having taken place without interfering with the form of their internal cavities, from the latter

being filled with the insoluble mineral, called by Dr. Mantell "moluskite" (yellow silicate of iron ?), allows the lime to be abstracted by a weak acid, and the origin of the calcareous grains thus ascertained: not only this, but the extreme faithfulness with which the internal cavities are represented, admits of the species of Foraminifera to which they belonged also thus being ascertained.

I have been particular in describing this deposit, because we shall find it so widely spread along this coast, not only here, but extending to the peninsula called Kattywar, on the coast of India, from whence it is imported into Bombay in considerable quantity, for building and flooring stone, supplying much the same place that the Freestone from Portland does on the southern coast of England. It is the deposit in Cutch and Kattywar called "Oolite" by Colonel Sykes (Trans. Geol. Soc. vol. v. p. 716), and the same, I think, which Colonel Grant terms "golden-coloured Oolite" (*ibid.* p. 298, and this vol. p. 412), in which form it is found in the creeks of the Runn nine miles north of Bhooj. The Ammonite, therefore, (if it be the same) which Colonel Grant found in it must have been a rolled specimen. This formation is not an "Oolite" either in structure or in a geological sense, though it has somewhat of the former; I shall therefore continue to call it Miliolitic Formation, or, for shortness of expression, Miliolite.

At Ras Abu Ashrin the coast sinks nearly to the level of the sea, and continues so for thirty-nine miles, or on to the bay called Ghobat Hăshish, where the same kind of white sandhills are again met with. I do not think this flat portion extends very far inland before it becomes bounded by the sandhills; indeed, I could see that it did not, from the high land of Masira opposite; nevertheless it is the lowest part of the South-eastern Coast of Arabia, unbacked by mountains, and the island of Masira, to which we will now pass over, lies opposite it, about ten miles distant.

Masira is thirty-five miles long, and varies from four to nine broad, and a chain of mountains runs longitudinally through it, which sends off spurs to the principal capes. This chain is chiefly composed of igneous rocks, and its highest mountain, which is in the northern half of the island, is not more than 600 feet above the level of the sea, while hardly any in the southern half of the island exceeds 300 feet. Here and there tracts of a fawn-coloured limestone formation present themselves, but these are of small extent, and chiefly raised up upon peaks of the igneous rocks. Besides the main chain, which, through its spurs and ramifications, extends nearly all over the island, leaving only here and there, on its inner side, some sandy plains,—there are other small ridges and rocks, which run more or less round the margin of the island, and some in the southern part of the channel, between Masira and the

main land, the latter making their appearance only in reefs and small rocky islets.

To the igneous rocks and the limestone there may be added a coarse modern formation, composed of sea-sand, in which are imbedded shells, corals, and pieces of the older rocks. Let us now turn our attention to a more particular description of these formations.

The igneous rocks are chiefly composed of euphotide and diorite, such as we have before seen at Ras Jibsh and Măskat (I shall henceforth use the term "euphotide" for serpentine); but, in addition to these, there are more or less homogeneous, green and black compact traps, amygdaloidal trap, the cavities of which are filled with calc-spar, and basaltic rocks, more or less scoriaceous, cellular, and phonolitic.

The euphotide is seen as usual in conjunction with its companion diorite, though not, I think, so plentiful. They form the main chain and principal masses in the island. In structure the diorite is coarse, and contains large crystals of hornblende, as at Jibsh, but of a greater variety of colours, such as green, brown, deep dark red, and black, sometimes in equal quantity with the compact felspar, at others preponderating. The northern extremity of the island is composed of a mass of trap rocks, of fine, compact, subcrystalline structure, homogeneous appearance, and sparkling black colour; its summit is 200 feet above the level of the sea. The same kind of trap appears in many other parts of the island and also in the islets. The green traps and amygdaloids form low round hills, of considerable extent; and the cellular and phonolitic basalt much higher hills, with loose portions on their sides, which are weathered smooth, and of a dark red-brown colour.

The accessory minerals which I met with were epidote, with calc-spar, and micaceous iron ore, tremolite, hornblende of different colours, and diallage, with its varieties, also copper. The latter mineral exists in many parts of the island, chiefly, I think, among the fine-grained green, earthy diorites, and low trap hills. I found it in the form of malachite, disseminated and in small lodes in the parent rock, also accompanying veins of hyaline quartz which traversed it. In many parts it has been worked, as the excavations and remains of slags and smelting-places in various parts indicate, but the weather-worn state of those I saw would make the time at which this took place very remote, and whenever this occurred, the yield must have been so trifling, even in the best places which came under my observation, that no copper-mining operations here at the present day could be carried on with profit. A short report of these copper veins was sent to the Government of Bombay, and subsequently printed (Journ. Bombay Branch Royal Asiatic Society, vol. ii. p. 400).

From the igneous rocks, let us go to the tracts of limestone. These

are isolated, of small extent, and for the most part raised on the tops of the older igneous or dioritic rocks, as at Măskat. Beginning at the northernmost end of the island, we find a tract commencing just inside the group of black trap rocks which forms this extremity, and from thence extending longitudinally for about five miles, making the central ridge or highest elevation of this narrow part of the island. It is scarped towards the west, and slopes into the sand of the sea-shore on the eastern side, at the same time that it rises towards the south-west, so that the dip of its strata is towards the east, and that of its strike north-east. For a long way the ridge or upper line of the scarp is not more than 30 or 40 feet above the level of the sea, but at its southern extremity it rises suddenly to about 100 feet. Here it presents a remarkable trifid rent, giving rise to three great fissures, which run from a central point in different directions towards the sea on each side of the island, respectively. The thickness of the scarps thus formed is from 60 to 80 feet, and their geological section from above downwards as follows:—

	Ft.
Compact limestone, of a whitish yellow colour, cleavable, but breaking with a rough fracture; more or less filled with the remains of shells and corals	40
Coarse, loose, sandy, silico-calcareous limestone, of a yellow colour, containing numerous shells	10
Same deposit, traversed by veins of gypsum	10
Coarse, arenaceous, yellow limestone, more or less shelly, which becomes lost beneath the bottom of the fissure.	

Returning to the inner shore of the island, by one of these fissures, I passed (after issuing from it, between the scarp of the limestone ridge on my right hand and the igneous rocks of the island on my left) over loose gritty earth of bright red and yellow colours, the finer parts of a jaspideous conglomerate that lay beneath. This conglomerate, I thought, might be a lower deposit of the limestone formation thus altered, which would then make the section of the latter correspond with that at Măskat. The pebbles of this conglomerate have been so changed, by the heat to which they have been exposed, that it is impossible to say what they were originally. In it, also, are disseminated here and there small quantities of malachite, which is the case in the siliceous conglomerate of the limestone formation that rests upon diorite at the village of Darzit, north of Măskat.*

The second tract of limestone we come to, proceeding south-westward, is raised on the top of the main chain of dioritic rocks, in the centre

* It is, perhaps, also worth remembering here, that the bed of cornelian pebbles or "cornelian mines" as they are called, near Ruttunpoor, on the lower part of the Nerbudda, in Western India (see p. 491), is in yellow sandy clay, which, with the pebbles, has in some parts become red and agglomerated apparently by heat; while close by, in the Rajpipla Hills, where this bed of cornelian pebbles exists, is also to be found nummulitic limestone.

of the northern half of the island. Its surface, which is horizontal, is 400 feet above the level of the sea, and its form very conspicuous from a distance, on account of its horizontality, and the contrast of its light yellow colour with the dark rocks around and beneath it. This tract is of an irregular shape, and about two miles long by a quarter of a mile broad, and its longest diameter is parallel with the longitudinal axis of the island. The southern extremity of its upper surface or plateau, which is attenuated, and not more than 50 feet wide, is undermined on each side for upwards of 15 feet, which leaves only a support of about 20 feet wide in the centre ; other parts on this side of the plateau are similarly worn, while there is nothing of the kind on the other sides. This leads one to infer that these excavations were effected by the waves when this limestone tract might have been rising from the sea. The fact also of their being only on the south-western extremity strengthens this, from the north-eastern part being sheltered by the coast, and the opposite side being directly exposed to the south-west monsoon. The surface of this plateau, which is perfectly horizontal, and the strata of the whole mass parallel to it, is bestrewed with the casts of bivalve shells, charged with the remains of minute Foraminifera, in the same manner as the hills about Hyderabad in Sinde, and among these the casts of large species of the genus *Lucina* are by far the most prevalent in both localities.

The following is a geological section of this tract from above downwards :—

	Ft.
Compact limestone, of a whitish colour, cleavable, and breaking with a rough fracture : more or less filled with turbinated and bivalve shells and microscopic foraminifera	100
Coarse yellow limestone, more or less sandy, chiefly presenting the remains of corals, about	50
Loose yellow silico-calcareous sand, and red and green arenaceous clays, about 50 feet; the upper two-thirds, consisting of the sand,—traversed by veins of gypsum; and the latter, consisting of the clays which form the base of the series, and rest upon the diorite	50

Although this series becomes arenaceous towards its lower part, I did not perceive a conglomerate here to bear out my inference respecting its existence at the base of the last tract, which is not exposed. The only fossils brought away were the following :—

Corbula ?—*Species ?* (Cast.) Trigonal, inequilateral, inequivalve. Breadth $4\frac{1}{4}$ inches, height $3\frac{1}{2}$ inches, depth $1\frac{4}{12}$ inch. Thick posteriorly ; compressed anteriorly. *Loc.*—Masira, from the surface of the plateau.

Spondylus Rouaulti, D'Arch. *mihi* (Foss. de l'Inde, pl. xxiv. fig. 6). Subovate, inequilateral. Breadth $1\frac{5}{12}$ inch, height $1\frac{1}{2}$ inch, and depth $\frac{10}{12}$ inch. Striæ numerous, close together, and thin, the largest bearing small spines. *Loc.*—Masira, from the second tract of limestone.

Although I could perceive traces of numberless fossils in this limestone, the only ones that I saw weathered out were the bivales on the plateau, and the one last mentioned.

Adjoining this tract of limestone are two others, which are only separated from it by a deep ravine: they are a little less in size, and slope towards the east with the tops of the igneous rocks on which they are supported. I had not time to visit them.

The next tract I shall describe is by far the most interesting of all, on account of its animal remains. Proceeding south-westwards, we come to this about two miles from "the plateau," but it is not similarly situated as to height, for its base is barely raised above the level of the sea, from which it is about a mile inland, among the igneous rocks. Like the south-west extremity of the first tract, this has also been raised by a force applied from below, here in the centre of the mass, which has produced a radiated fracture of the whole, and thrown its parts widely asunder, so as to expose a floor beneath, now half a mile or more in diameter. This floor happens to consist of a stratum of small nummulites, which reveals the nature of the limestone tracts hitherto examined, and establishes the existence of the Nummulitic Series on this part of the South-eastern Coast of Arabia.

The limestone, which rises about 100 feet above this floor, is of the same kind as that already described, and the fossils obtained from the inclosed area, which presents a vast variety, are as follows:—

FORAMINIFERA.

Nummulites Garansensis, Joly at Leym. Comparatively sparsely scattered among myriads of smaller and more globular ones of the same (?) species (*vide antè*, page 544), accompanied by Crabs, Echinodermata, &c.

ECHINODERMATA.

Spatangus.—*New Species ?* Conical. Length 6½ inches, breadth 5½ inches, and height 5 inches. Ambulacra four, not depressed, spreading from the centre of the summit of the test, and extending nearly to the margin; grooved anteriorly in the place of the fifth ambulacrum. Genital pores four. Mouth bilabiate, between the centre and anterior extremity. Base oval; carinated in the centre, from the mouth backwards, and covered with small tubercles; bordered on each side by a longitudinal area of smooth polygonal plates. Vent terminal supra marginal. *Loc.*—Masira. *Obs.*—The remains of this large fossil were very numerous, and partly filled with the nummulites mentioned.

Spatangus.—2nd *Species ?* (Incomplete.) Length 2 inches, breadth 1½ inch. Ambulacra five, petaloid, situated in deep furrows, spreading from a point nearer the anal than the oral extremity; the posterior two shortest. *Loc.*—Masira.

Cidaris.—*Species ?* (A portion only of the test, bearing two big tubercles.) The largest $\frac{7}{24}$ inch in diameter at the base, surrounded by a ring of small tubercles, but none within the circle. *Loc.*—Masira.

CRUSTACEA.

Cancer (*macrocheilus*, *mihi*). Carapace subelliptical; diameter $5\frac{1}{4}$ inches transversely, 4 inches antero-posteriorly. Spiniferous laterally; spines five in number, alternately bifid, extending from the orbits backwards; orbits $2\frac{1}{4}$ inches apart. Pinchers large, expanded, equal in size, concave on the interior surface, and bordered on the posterior edge by eight tubercles; tail consisting of six segments. *Loc.*—Masira.

CONCHIFERA.

Tubicola.—*Species ?* (See a description of this tube among the fossils from Hammar el Nafur, further on.) *Obs.*—They abound among the nummulites in Masira, and are very common in Sinde.

The deposit in which these fossils were imbedded bears little trace of them when not weather-worn or disintegrated, so that this might partly account for my having passed them over in the other limestone tracts. Here they abounded all ready to my hand, but being alone when I fell in with them, and the sun having set, I could not examine the place so much as I wished, nor bring away so many fossils as I desired, and the next day we removed to a station several miles distant; so that I had not an opportunity of returning to this really garden of fossils,—much to my regret.

The last unmentioned tract of limestone in this island is that which forms two mountains 500 feet high, at its south-western extremity. It is a narrow portion, about a mile long, and raised, as usual, on peaks of diorite. There were no loose fossils about it, and the character of the limestone I have already described. Its base is buried in the *débris* of the superincumbent mass.

All these tracts are doubtless parts of the same limestone formation, which was once continuous over the island of Masira, but has since been broken up by the eruption of its igneous rocks, and more or less carried away by the action of the waves, during the time that the island has been gradually rising from the bottom of the sea to its present position. The presence of the bed of nummulites, too, in one portion of it, shows also that the whole belongs to the Nummulitic Series, and the formation generally agrees in composition, yellow colour, and stratification, with that resting on the serpentine and diorite rocks at Măskat.

Having now described the two principal formations in the island of Masira, viz. igneous and aqueous, let us turn our attention for a few minutes, before returning to the main land, to the more modern formations to which I have alluded. These are two in number, one of which,

perhaps the latest of the two, is seen in the north-eastern part of the island, where it is about 12 feet thick, and raised about 40 feet above the level of the sea, about a mile from it. It runs parallel to the north-eastern extremity of the island, being scarped on its seaward side, and on the other thinning off upon the rocks on which it is supported. In composition it consists of shells, and pieces of coral, from which the animal matter has disappeared, also portions, more or less rounded, of the limestone and igneous rocks of the locality, all of which are slightly held together by sea-sand, which is but a minute form of the same kind of material. This formation here lies between the two groups of igneous rocks which form the two angles of this truncated extremity of the island, and is firmly adherent to their sides.

The other formation, which is but a finer deposit of the last mentioned, and perhaps a little older, is considerably elevated above the sea. It may be seen close to the village of Gyren, on the inner side of the south-western half of the island, and only differs from the miliolite of the opposite coast in containing more particles from the igneous rocks, and being raised on the top of some greenstone peaks, about 200 feet above the level of the sea.

Before concluding my remarks on Masira, I should mention that in the north-east half of the island, a little inland of Ras Jazirăh, there is a small low mound of aqueous strata, projecting from the plain of igneous rocks which has been rendered jaspideous by heat; the strata are in a vertical position, and composed of an extremely fine flinty material of a red or flesh colour, probably originally a fine clay. They are undergoing fragmental disintegration, and the pieces very much resemble *leelite.* To what formation this belongs I cannot say, but probably not to the nummulitic formation of Masira, for that rests on the rocks in which this appears to be enveloped. I have mentioned the existence of a similar mound and strata, similarly situated, at Ras Jibsh.

Returning to the main land, to the bay called Ghobat Hashish, which is opposite the south-western extremity of Masira, and to which we have already brought on the low land behind this island, and the sand-hills from Ras Abu Ashrin, we find the compact nummulitic limestone again appearing from beneath the Miliolite. This is seen on the western side of the bay, where it is about 80 feet high, after which the cliff rises gradually on to Ras Jazirăh, about 100 miles distant, where it is about 480 feet above the level of the sea; and the direction of this part of the coast, being due south, as I have before stated, shows also that the strata gradually rise in this direction, as well as to the south-west, which we shall better see presently.

For the specimens and information I possess of this part of the coast I am indebted to the kindness of Lieutenant Grieve, who surveyed it in 1847.

Rock-specimens from the west side of the bay of Hashish, and from Ras Sărāb, about twenty-five miles south of it, show that the limestone formation, which here emerges from beneath the sandhills, consists of a fine compact rock, some of which is magnesian, heavy, and of a grey colour.

Next comes the little island called Hammar el Nafur, which is about twenty-five miles south of Ras Sărāb, and of all the information which Lieutenant Grieve has communicated to me, that from this little island and another cape next to it, ealled Ras Kariat, with their specimens, are by far the most interesting and important. It is extremely fortunate that this little island should exist just here, at the eommencement of the rise of the cliff, whieh we shall find by-and-bye carried up 4,000 feet above the level of the sea far beyond our reaeh; for from its form and position, together with the eape mentioned, we obtain an unmistakable geologieal section of the eliff for 320 feet down from its summit, whieh is the height of Hammar el Nafur.

This island is about 400 yards long by 300 broad, and its summit, though flat, is split in all directions. Rock-speeimens from it show that it is composed of compact white limestone, and coneretionary flints above, the former breaking with a more or less smooth fracture. This is stated to extend down 150 feet, and to present no loose fossils. Then comes 50 feet of white earthy or gritty caleareous deposit, more or less mixed with argillaceous matter, of a greenish-white colour, in which there are many fossils; and the rest is stated to be greenish-white clay, without any; the bottom of the sea everywhere in the neighbourhood being composed of the latter material.

This clay, just stated to be of a greenish-white colour, is meagre to the toueh when dry; breaks with an irregular rough fraeture; receives a polish when scraped with the nail; does not adhere to the tongue; does not effervesce with aeids; does not mix readily with water, but, when once rubbed up with it, remains for many days suspended in it in an impalpable powder. Before the blow-pipe it dries up, becomes red and porous, and then passes into a black slag. When in combination with more or less calcareous material, it forms an excellent soap.

Having described this clay, I will now add a list of the fossils which Lieutenant Grieve sent me, and with them include those whieh came from Ras Kariat, nearly opposite, since the strata and fossils of both places are said to be exaetly the same, and the specimens confirm this. They are as follows:—

FORAMINIFERA.

Nummulina.—*Nov. sp.?* Circular, compressed, terminating at the circumference in a thin edge. Breadth ¼ ineh, thickness $\frac{1}{16}$ inch; surfaces smooth, without any marking; spire composed of 9—10 whorls,

chambers longer than broad after the third whorl, hardly distinguishable above and below the central plane. *Loc.*—Hammar el Nafur and Ras Kariat, in the gritty calcareous deposit below the compact limestone.

Obs. This is very like *N. Caillaudi*, D'Archiac and J. Haime (Fos. de l'Inde, pl. i. fig. 9, &c.), in the sections, having also a central cell; but otherwise it is smaller, more compressed, and thin instead of round at the margin. If not young individuals of a larger form in the neighbourhood, these nummulites might perhaps be considered to belong to a new species.

Echinodermata.

Echinocyamus.—*E. pyriformis*, Ag. *mihi.* (Tab. 27, figs. 19—24, *et Echinoneus placenta*, Goldf. Tab. 42, fig. 12.) Subpentagonal, oval. Length $\frac{13}{24}$ inch, breadth $\frac{12}{24}$, height $\frac{3}{24}$. Subtruncated anteriorly, pointed posteriorly; mouth central; vent inferior, and situated a little nearer the margin than to the mouth. *Loc. idem.*

E. siculus, Ag. *mihi.* Oval, depressed. Length $\frac{8}{24}$ inch, breadth $\frac{7}{24}$ inch, height $\frac{2}{24}$ inch. Mouth and vent the same as in the foregoing species; ambulacra five, petaloid, not depressed. *Loc.*—Hammar el Nafur and Ras Kariat.

Obs. This, and the foregoing species, are numerous in the earthy deposit below the compact limestone, together with the nummulites, which, on the other hand, are scanty, judging from the specimens of the deposits sent to me, but they are probably more numerous in other parts.

E. ——— ? (Impressions only.) 1st *species ?* Oval. Length $\frac{8}{12}$ inch, breadth $\frac{6}{12}$ inch.—2nd *species ?* Circular. Diameter $\frac{5}{12}$ inch. *Loc. idem.* *Obs.*—Found in the marl passing from the gritty calcareous deposit into the clay.

Echinolampas Sindensis, D'Archiac (Fos. Num. de l'Inde, pl. xiv. fig. 2). Sub-pentagonal. Length $2\frac{8}{12}$ inches, breadth $2\frac{3}{12}$ inches, height $1\frac{5}{12}$ inch. Summit subcentral, anterior; ambulacra five, petaloid, in furrows, each enclosing a raised area; genital pores four; none posteriorly, mouth subcentral, depressed, surrounded by five tubercles, or projections, with a groove between each, presenting ambulacral pores; vent submarginal. *Loc.*—Ras Kariat.

Conchifera.

Tubicola.—*Serpula ? recta*, Sow. Tube circular. Diameter $\frac{1}{2}$ to 1 inch; slightly increasing downwards. Straight or slightly crooked; sometimes bent at an obtuse angle; length unknown. Wall of tube, from the thinness of a wafer to $\frac{1}{12}$ inch; composed of concentric layers, smooth and round internally; uneven, and presenting transverse striæ or rugæ externally. Filled with the gritty material in which they are imbedded. *Loc.*—Hammar el Nafur, Ras Kariat, Masira.

Teredo Navalis.—*Species ?* Tube subcircular. Diameter above $\frac{1}{4}$ inch, increasing slightly downwards to a point, where it suddenly dilates; subflexuous; length of specimen $2\frac{1}{2}$ inches, real length unknown. Divided internally above by a longitudinal septum, which ends below the dilatation of the tube in the two compartments becoming separate siphons, which are in contact in the middle, but entirely separated from the walls of the tube. Wall of tube $\frac{1}{24}$ inch thick; external surface uneven. irregular; striæ arranged longitudinally, and becoming circular where the tube suddenly expands. *Loc.*—Hammar el Nafur and Ras Kariat.

Obs. The first of these tubes abounds in the earthy limestone or marly deposit with the nummulites, both here and in the island of Masira. They are also very common in Sinde. A specimen of one is figured in pl. xxi. fig. 1 of Grant's Geology of Cutch (*loc. cit.*), where it has been provisionally called "*Serpula ? recta*" by Mr. Sowerby. It appears to have been the wall of a Pholadine animal. Such tubes of a modern date abound in the blue clay of Bombay, where they are for the most part found in half-lignified roots and branches of small trees (Mangrove ?).

Conchacea.

Lucina.—*Species ?* (Cast, imperfect.) Circular, compressed, equivalve, presenting little tubercles in circular depressions on both sides, which appear to be impressions of the mantle. Breadth about $2\frac{9}{12}$ inches, and length $2\frac{9}{12}$ inches. *Loc.*—Hammar el Nafur.

Obs. This is a fac-simile of one of the casts of *Lucina* found commonly about the hills at Hyderabad in Sinde, and like those on the surface of the plateau in Masira. It is a characteristic fossil of the upper part of this series, from which therefore it most probably came in the island of Hammar el Nafur.

Gasteropoda.

Natica.—*Species ?* (Cast, imperfect.) Breadth $4\frac{1}{2}$ inches, and length $3\frac{1}{2}$ inches. *Loc.*—Hammar el Nafur and Ras Kariat.

Obs. There are several imperfect casts of large *Naticæ* from the softer limestone of these localities. In Sinde also such casts are found richly charged with large nummulites, together with minute and small Foraminifera. They, therefore, in the absence of the larger nummulites, here assist in establishing the geological age of the deposit in which they are found; throughout which, the shells of the Conchifera and Gasteropoda would seem to have entirely disappeared, as in most other parts of the Nummulitic Series with which I am acquainted; nothing remains but the internal casts. So much for the fossils of this locality.

Before proceeding further, it is worth while to compare the strata of

the island of Hammar el Nafur and Ras Kariat, on the main-land, with a section of the nummulitic strata forming the range of hills at Sukkur, in Sinde. This section was kindly sent me by Dr. J. P. Malcolmson, of the Bombay Medical Service, who states in his letter as follows :—" I have been over the Sukkur range of hills to their termination at Daji Kot. There is but little diversity in the whole range, which in no place exceeds 400 feet in height. The whole is one mass of nummulitic limestone, more or less disintegrating. It is, however, strange that the upper strata are in many places *very compact, and contain but few fossils, but are very plentifully interspersed with flints ;* some of the flints contained large nummulites. The escarpment of the whole range faces the west. The strata are perfectly horizontal. Some of the limestone is of a cream colour, and forms a good building stone, which wears well, and does not seem to suffer from atmospheric exposure. About twelve miles from Sukkur I found a bed of clay *underlying* the nummulitic limestone, filled with the impressions *only* of shells. [This clay, of which Dr. Malcolmson sent me a specimen, appears to be of the same kind as that at Hammar el Nafur.] The hill is here 250 feet high, and composed entirely, in the lower part, of nummulites, overlaid by compact limestone, containing flints. I traced the out-cropping of the clay for about half a mile."

Here, then, we have nearly the same strata as at the island of Hammar el Nafur and Ras Kariat, and that too about the same height, viz. 400 feet,—composed of compact limestone above, then nummulites in a loose disintegrating (gritty ?) deposit below, and afterwards clay.

It is important to establish the exact nature of this series at Hammar el Nafur and Ras Kariat, for the reasons I have before stated, viz. that as the cliff rises towards the south-west we shall soon find these strata elevated beyond our reach, so that when we come to the height of 4,000 feet we may have to assume that they still form the summit there, from their existence at Hammar el Nafur and Ras Kariat; unless we can prove this by the presence of the nummulites themselves, or some other allied fossil. The disintegration of the deposit in which the great mass of nummulites are imbedded, I have generally observed to be the case in all the specimens I have seen from Egypt, Sinde, and Cutch. I have not yet seen a compact hard limestone charged with nummulites.

When the foregoing paragraph was written I thought that the nummulitic formation was raised with the great white limestone series of the SE. coast of Arabia. I have now, however, every reason to think that the opposite is the case, as will hereafter appear, and that, instead of forming the summit, it runs throughout along the base of the great scarped surface of this coast, assuming that position somewhere about the part now under description.

Passing back to the coast, then, opposite the island of Hammar el Nafur, Lieutenant Grieve states this to be "low, and to present a range of small dark peaks, rising gradually from the beach." These are probably the tops of low igneous rocks, which we might expect to be near, from the break in the cliff and the upheaval of Hammar el Nafur opposite it.

The next place from which I have specimens is Ras Kariat, already mentioned. This cape is nine miles south of the island of Hammar el Nafur, and about forty north of Ras Jazirăh. From this point, the cliff, which is 280 feet high and has hitherto been in detached portions, is extended on continuously to within a few miles of Ras Jazirăh. The upper part of it, like that of Hammar el Nafur, is composed of compact white limestone, with concretionary flints, passing below into an earthy gritty one, thence into a marly deposit, and lastly clay. The fossils are the same as those of Hammar el Nafur, and have been described under the list from that island. I received also large portions of radiated and columnar crystallized carbonate of lime, pointed at the circumference, translucent, and of a greenish-white colour; they are crossed by transparent wavy lines, as if they had been formed by successive additions, and appear to come from the earthy limestone near the green clay; also specimens of gypsum, with which some of the tubes of the Tubicolæ were filled. The presence of gypsum here should not be forgotten, for it exists in the same position at Masira and the clay too, below the compact limestone and grit; indeed, the series is the same.

From Ras Kariat, the cliff, as before stated, extends on uninterruptedly to within a few miles of Ras Jazirăh, or a little beyond Ras Markas, which is nine miles from the former cape, where they are 480 feet above the level of the sea. Rock specimens from this show that the base is composed of a pinkish, compact, sub-saccharoid, magnesian limestone, which slowly effervesces with acids; also a rock of the same kind, but filled with the cavities of small shells, viz. Cardium and Cerithium, containing selenite. The Cardium is oblique, inequilateral. Length ½ inch, and breadth $\frac{5}{24}$ inch. We shall find a rock almost identical with this occurring in the Nummulitic Series at Makalla, about 600 miles SW. of it; the proximity, however, of igneous rocks, which we shall find in both localities, has probably influenced this resemblance, more than the continuity of the stratum.

Lastly, we come to Ras Jazirăh, the end of this portion of the coast, which now suddenly returns, from running N. and S., to its general direction, viz. NE. and SW.; and here we have another eruption of igneous rocks. This is confined to the cape and its immediate neighbourhood, but it presents as complete a picture of such a disturbance as can well be witnessed. The continuity of the cliff, which on either

side is uniform, and horizontal as far as the eye can reach, is here entirely broken up by the igneous rocks, and the detached portions of its strata thrown into all kinds of positions, and weathered into all kinds of shapes; while the dark rock appears between or below them, or in separate peaks, among the general wreck. Where the white strata overlie the igneous rocks, they are discoloured for some distance, red and black: this would seem to be the passage into the former, just as we saw it in the base of the plateau at Masira, where these coloured strata are composed of red and dark green clays; for the limestone here probably rests on dioritic rocks, as at Masira, and the rupture has been caused probably by their subsequent elevation, and by the effusion, perhaps about the same time, of more igneous matter. Specimens from the island which joins the cape at low water, and from which it takes its name, show that it is composed of a rock allied to the euphotide and diorite before mentioned, and of which probably the igneous rocks on shore are principally composed. These specimens consist of brown compact felspar, in which there is an equal quantity of sparkling laminated black hornblende, in small crystals; and on the plane surfaces of the specimens an ophiolitic or nephritic deposit, like that seen about the euphotide hitherto met with. On either side of this eruption, the cliffs, as before stated, are continuous, and their strata horizontal, as far as the eye can reach, but their whiteness, which hitherto has made them look so much like those on the south-east coast of England, seems here to cease, and to give place to a light yellow tint.

From Ras Jazirăh the cliff is continued on, with the exception of a break here and there (where it falls back and gives place to a sandy plain in front), to Ras Shaherbataht and Ras Gharau, which capes are within a few miles of each other. Here the cliff is 800 feet above the level of the sea, and has been gradually rising to this since leaving Ras Jazirăh, a distance of 110 miles. Captain Haines states that the upper strata here are composed of limestone, below which come "chalk" and flints.* As we approach this cape, we observe that the cliffs begin to present large caverns, which appear to have been solely excavated by the waves; they are very similar to those seen on the Bill of Portland. I could not help thinking that in this way most of the great caverns which we shall by-and-bye see in the mountains have been formed, and which now serve for the habitations of most of the Bedouins who live on the high land of Southern Arabia. At Ras Shaherbataht the same kind of uniformity and continuity of cliff meets the eye on either side as at Ras Jazirăh, only that it is nearly twice the height; but as we approach the centre of Kuriyah Muriyah Bay a totally different aspect presents itself: here we observe at Ras Shuamiyah, which is about 135

* Journal Royal Geograph. Soc. vol. xv.

miles from Ras Jazirăh, another and much more extended outbreak of igneous rocks than at the latter point. The cape called Ras Shuamiyah is formed by a dark black-looking igneous rock, and on either side of it black dikes irregularly extend up through the white strata, in some places raising them and running along between them, and in others attaining the summit and flowing along the surface above the cliff, the uniformity of which may well be conceived to have become totally destroyed by this eruption. In some parts it is raised higher than we have hitherto seen it, in others more depressed, while the land interiorly appears to have participated in this, if not in a former more general disturbance; and a few miles further south-west, its irregularities still increasing, brings us to the high land before mentioned, which is 4,000 feet above the level of the sea, with the white cliff we have been passing apparently at the upper part of it. This is the eastern limit of the elevated tract of Southern Arabia, and the western limit, on the coast, of the low land or Desert of Akhāf. The south-western part of Kuriyah Muriyah Bay is bordered by this high land, which, breaking down towards the extremity of the horn, ends in a granite mountain, 1,200 feet high, called Ras Nus.

The appearance of this granite mountain probably explains the grand and sudden upheaval of the coast here. It is the first granite we have met with, but we shall soon find that we have come to an immense tract of it, which not only extends along the coast south-westward for several miles, but also eastwards, where it forms the greater part of the Kuriyah Muriyah islands, to which we will now direct our attention.

They are five in number, neither of which is more than twenty-five miles from the coast; and the furthest apart are not more than thirty-five miles from each other, while they are all in the same parallel of latitude. The largest, called Hăllăniyah, is about seven and a half miles long, and about three and a half broad. The next in size is Soda, which is about three miles long and two broad. Haski and Jibliyah are each about a mile square, and Gharzaut is hardly more than a large rock.

Hăllăniyah is composed of about one-sixth limestone, and the rest of igneous rocks. The limestone occupies the northern part, and forms a cape 1,645 feet above the level of the sea; its colour generally is a light yellow to the water's edge, and its strata, though tilted up and displaced where they are in contact with the igneous rocks, are undisturbed at the cape, any further than is caused by their elevation of about fifteen degrees towards the north. The late Dr. Hulton, from whose description of these islands* the following remarks have been extracted, states :—

* Trans. Bombay Geograph. Soc. 1839-40, p. 189.

"About the centre of the island [Hällāniyah] the hills rise into a cluster of pointed spires, the highest of which was computed by trigonometrical measurement at 1,510 feet above the level of the sea; and from these, similar hills run in all directions, preserving in most cases the form of interrupted ridges. At the eastern [northern ?] extreme, the land assumes a different state; a perpendicular headland, 1,645 feet in height, boldly projects into the ocean, and for some distance to the westward appears a continued mass of table-land, accidentally heaved up, as it were, at the end of the island. With the exception of this high land the rest of the island is chiefly composed of granite, varying somewhat in its structure, and the proportion of its fundamental ingredients, upon which also depends a variety in its colours. The most interesting feature of the granite is the manner in which most of its ridges are surmounted by a dark-coloured rock allied in its characters to those of the trap order, more especially to greenstone. [The latter is our diorite, and the dark-coloured rock probably euphotide, which we have before seen to accompany it.] This is found passing through the body of the hills in the form of dikes. The same rock is seen abundantly in the form of veins and seams, traversing the granite in all directions. It would appear as though, by some powerful internal impulse, this substance had been injected into fissures in the granite, produced by the same violent action. To a person viewing it from a moderate distance, the distribution gives rise to an appearance of an unusually dark shade running along the summits of the hills, as most of our party at first fancied. These dikes and seams do not follow any general rule in regard to their direction, but are entirely influenced in this respect by the disposition of the granite, which follows no particular course. They vary from a fine vein of a few inches to a stratum of eighteen or twenty feet in breadth. In mineral composition, too, they differ no less materially. Most of it I have stated to resemble greenstone, in the compactness and simplicity of its structure, and hornblende appears to be the predominant ingredient; but by the intermixture of felspar in greater or less quantity, rocks of a very different nature result, still occupying the same relative situation. In some places the felspar is disseminated in the form of distinct crystals, communicating a porphyritic structure; in others quartz is abundantly intermingled, giving it more of a granitic aspect. In the latter there is a tendency in the compound to diffuse itself more extensively through the granite bed, losing its character as a stratum, and entering largely into the formation of the hill itself. In fact, it appears to undergo, by this accession of felspar and quartz, a regular transition to granite itself, and merely differs, as far as the eye can judge, in colour, which, from the presence of hornblende as a subordinate mineral, becomes of a dark

speckled hue . . . . In both this and the prevailing kind of granite, mica, if not altogether wanting, is a very scarce ingredient, and is found chiefly in the light-coloured veins of granite intersecting the granite mountains."

There can be no doubt, I think, that this is an altered state of the euphotide already described; the author knew greenstone (diorite), he also knew granite and trap; and there is no other "dark coloured rock," that I saw, in this part of Arabia, "allied" to greenstone, but "euphotide."

Since the foregoing paragraph was written I have been presented with several geological specimens from this island, among which there is an intensely dark, crystalline euphotide richly charged with pinch-beck diallage, so that I am probably right in my conjecture respecting the rock to which Dr. Hulton has alluded.

"The eastern end [northern ?] of the island is that which attains the highest point of elevation, and is composed of a secondary limestone pretty regularly stratified towards the sea. It contains in its substance a few fossil shells, but is not remarkable for anything further than its proximity to the granite, its greater elevation above the sea, and its insulated situation. It is nowhere intersected by veins of either granite or greenstone.

I know nothing myself more of this island than that which I have stated previous to quoting Dr. Hulton's description, and have nothing to remark further respecting it than that I would direct attention to the depth of the limestone strata here, which we may find useful by-and-bye in determining its real depth throughout the neighbouring coast.

The small rocky island of Gharzaut, which is a little NNE. of Hällăniyah, and 200 feet high, is composed "exclusively of granite of a reddish colour, and a fine crystalline structure."

Soda, which is six miles west of Hällăniyah, presents a peak 1,310 feet above the level of the sea. The composition of the hills is granitic, with the same distribution of dark-coloured strata as that noticed on Hällăniyah, though not quite so conspicuous. "The granite on the eastern end, and on the central part, is of a dark grey colour, with extensive veins of a light colour, traversing it in various directions. That on the western end is a mixture of red and grey granite, in varying proportions, the red preponderating in most localities, and of a fine texture, similar to that of Rodondo [Gharzaut]."

The geological structure of Jibliyah, the highest point of which is about 500 feet, is stated to be "essentially primitive, but with a greater variety in the appearance of the rocks than we found at Hällăniyah. The outer detached rocks are of similar composition, being formed of a species of dark-coloured granite, in which hornblende appears to enter

largely. The island itself is composed of porphyritic sienite, the colours of some specimens affording a rich and diversified appearance."

Haski, the most western of all these islands, and the nearest the shore, presents in its highest peaks an altitude of about 400 feet. "In its geological characters, too, it is nearly similar [to Jibliyah], though the reddish-coloured granite, which is common in Soda, is here found to constitute the greater portion of the island, the remainder being composed of a species of variegated granite and porphyry."

Thus we see that these islands are, with the exception of Hăllăniyah, all composed of igneous rocks, and that, too, chiefly of granite ; and we also see that they are all nearly in the same parallel of latitude as the village of Hasek, which is only nine miles north of Ras Nus, the south-western extremity of Kuriyah Muriyah Bay, and which itself, as before stated, is also formed of a granite mountain. Further, if we look at Captain Haines's beautiful chart of Kuriyah Muriyah Bay, we shall not find a sounding of 50 fathoms north of this little chain of islands and a line extending from them to Hasek, that is, between them and the main land to the north, while immediately south of them and this line the soundings sink to 145 fathoms, and no bottom, showing that there is a great depression on this side, which we also learn by the soundings to be continued westward to Ras Nus, and along the coast as far as Marbat, where the granitic tract ends.

Returning again to the shore, we find ourselves opposite a very different coast to that we have just passed: one now of 4,000 feet instead of 800 feet above the level of the sea; and commencing from Ras Nus, where we left off, which is the seaward point of demarcation between the low and high land, we find the granitic tract on shore to commence here (though at sea it begins much further eastwards, as we have seen in the Kuriyah Muriyah islands), and to extend on to Ras Marbat, a distance of forty miles, where it ends. At first it is narrow, and runs along the base of the broken-down table-land, but the latter, soon falling back, gives place to an expansion of it into a low field of igneous rocks, which is about ten miles wide, and terminates at the cape mentioned. This field, which is backed by the precipitous declivity of the table-land, presents an almost uninterrupted uniformity in its lowness, except at one point, near the sea, where an isolated pyramidal mountain, supported apparently by granite, remains, as a type of what once existed over the whole area. This mountain or pyramid, called Jibal Jinjări, which is 1,300 feet high, is stated by Captain Haines to present chalk and gypsum in its composition; and so far it is interesting, because we know that these two substances exist in a fixed part of the Nummulitic Series at the island of Hammar el Nafur and Ras Kariat, where its summit is only 320 feet

above the level of the sea. By chalk here is meant a soft, white, earthy limestone, or gritty calcareous deposit belonging to the Nummulitic Series ; there is no genuine chalk on this coast that I have met with, though the former is a close approach to it, and, in the absence of the latter for comparison, might easily pass for chalk.

In the immediate vicinity of Ras Nus the limestone strata, capping the detached and broken-down masses of the table-land, are much and variously inclined, while a similar disturbance is evinced by the older igneous rocks of the low plain which follows, from the variety of coloured dikes with which they are veined. I explored about a dozen square miles of these rocks near Marbat, and also ascended the precipice of the table-land at this point, the particulars of which will now occupy our attention.

The igneous rocks, as before stated, terminate at Ras Marbat in a low plain, which shelters a little bay and village of the same name on its inner side, that is, between it and the main-land. This plain is about four miles square, and 30 feet above the level of the sea in its centre, from which it gradually slopes on all its free sides to the sea. It is more or less wavy, and here and there interrupted in its continuity by irregular fissures running to the sea, and by projections a few feet above the surface of the granite rocks of which it is composed, while at the bottom of the bay is a group of granite hills, about 100 feet high.

The igneous rocks of this plain and its neighbourhood consist of red and grey granite, red protogine granite with black hornblende sparsely mixed with its chlorite, sienite, euphotide, coarse and fine-grained diorites, and a breccia consisting of pieces of a green chlorite rock and fine compact brown limestone cemented together by calcareous matter ; to these may be added gneiss, which appears in vertical strata in the midst of the groups of red and grey granite rocks projecting from the plain.

The red protogine granite appears to be the most abundant; and the grey granite the oldest in appearance, though the line of demarcation between the two is by no means evident, for they seem, so far as I saw, to pass into each other.

The granite hills on the inner side of the plain at the bottom of the bay have been thrown up through fine compact greyish-brown limestone strata, which form a part of them, and, from its effervescing so slowly with acids and its heaviness, is probably more or less magnesian. It also, when minutely examined, presents laminæ of mica, which in some way or other have been transported into it. This limestone, where weather-worn, is exactly like the weather-worn, compact limestone of the great scarp above, which we shall find out by-and-bye to belong to the Cretaceous Period.

I did not see the rich red granite, grey sienite, euphotide, diorites,

or chlorite breccia *in situ*, and therefore only infer their existence here from having picked up pieces of them in different parts of the plain; but there can be hardly any doubt of the fact, for I do not see how they could have come there otherwise.

With these few observations on the igneous tract, which is about ten miles broad, let us pass across to the base of the scarp of the table-land; and, fortunately for our examination of this, there is a dry bed of a great torrent, which empties itself into the Bay of Marbat, on the inner side of the granite hills, and which, running along the base of the declivity for two or three miles, completely separates it from the igneous rocks, and exposes its strata unobscured by *débris* for several feet below the surface of the immediate neighbourhood.

The precipitous face of this table-land here is scarped for about two-fifths of the way down, and then slopes outwards in ridges, like great buttresses, which, parting from the base of the escarpment, in pointed extremities, expand out to a great extent as they reach the plain below. Commencing, then, from the summit of this escarpment opposite Marbat, where it is 3,400 feet high, and where the torrent bed before mentioned is 20 feet deep, we have approximatively, from above downwards, the following geological section, viz.:—(For a sketch of Marbat and section, see Pl. XXIII.)

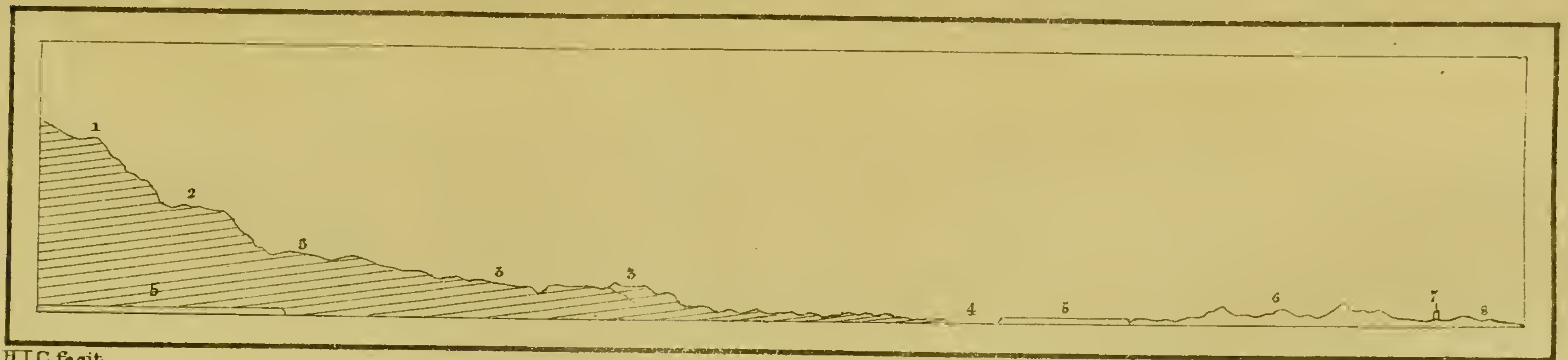
	Ft.
White limestone strata	1,400
Argillaceous strata of a red colour	300
Coarse micaceous sandstone, of a yellowish brown colour, becoming finer as we ascend	1,700

These divisions I will now describe in detail; and, beginning from the base, we find the sandstone of a compact gritty structure below, becoming finer as we ascend; massive at first, but becoming thinly laminated, then in the upper part thicker again, and jointed; breaking with a rough earthy fracture throughout; of an ochrish brown colour, and ferruginous aspect below, becoming more yellow above, and then of a chocolate-brown colour at the top; presenting mica throughout, but more in some parts than in others, though diminishing generally in quantity towards the upper part.

The chocolate-brown coloured, fine deposit of this sandstone passes into the argillaceous division, which presents strata of various colours, but chiefly red; one of which, a dark-red clay stratum, of a soapy nature, presented an excavation which the Bedouins told us was made by their women, who came there occasionally to eat the clay,—whether from hunger or a vitiated taste I could not discover, but probably the latter.

These red strata pass into white and grey, compact, limestone strata, more or less thick, more or less fine in structure, more or less lithogra-

Marbat Peak 3400 ft.



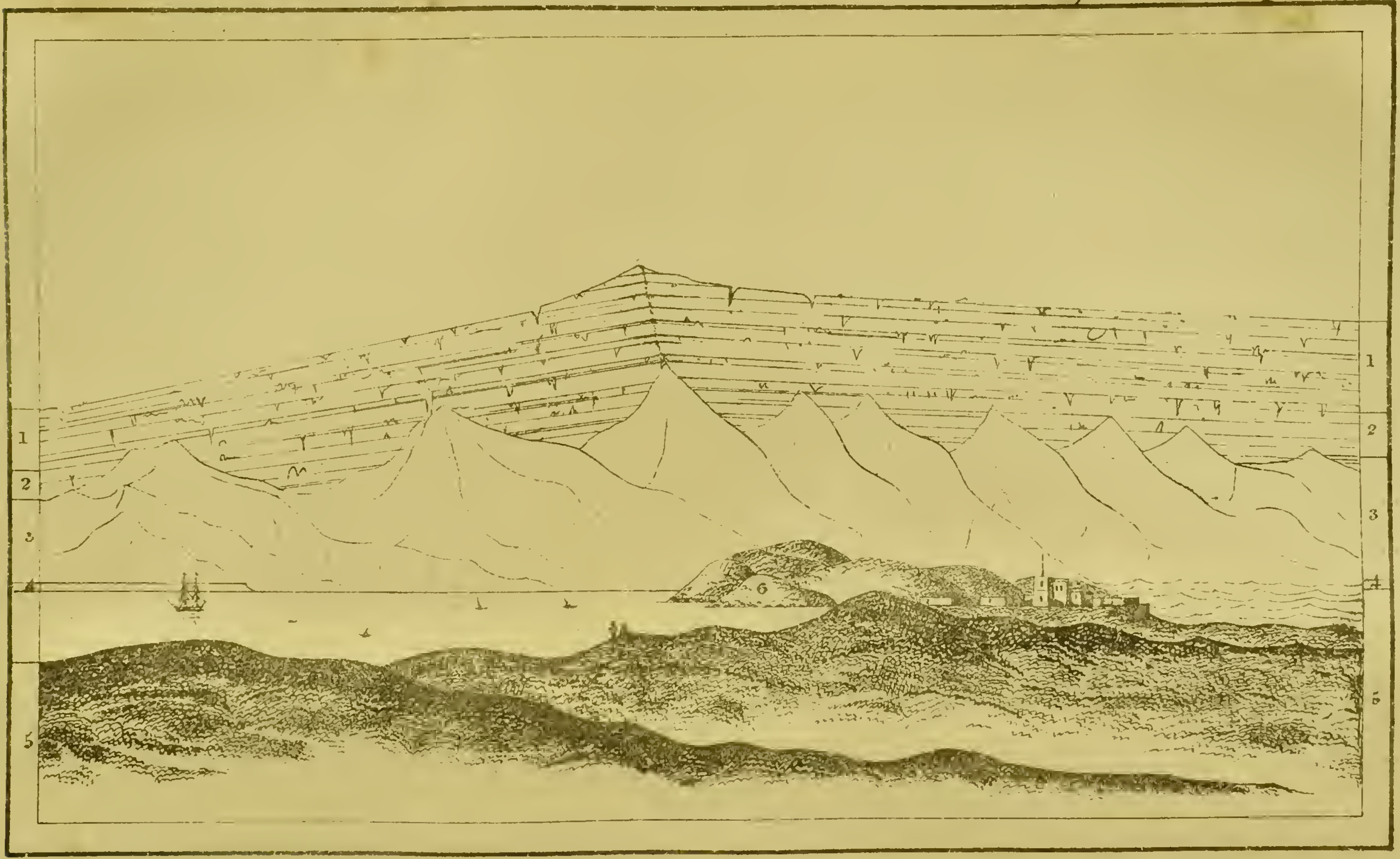
H.I.C. fecit.

B.E.S. Press.

Section from Marbat Peak to Marbat Plain from the West.

1 Marbat Peak-White limestone. 2 Red Argillaceous Strata. 3,3,3 Miocene Sandstone. 4 Debouchment of Torrent Bed. 5,5 Nummulitic Series. 6 Granite Hills

7 Village of Marbat. 8 Granite Plain.



MARBAT

1 White Limestone. 2 Red Argillaceous Strata. 3 Micaceous Sandstone. 4 Nummulitic Series capped with Miliolite

5 Granite Plain, capped with Miliolite 6 Granite Hills embedding blocks of Limestone.

phic in appearance, above which comes a whitish yellow, chalky deposit, more or less argillaceous, from which the Bedouins cut their pipes, and then a white, compact limestone again. The latter lies in heaps of bare rocks, weathered into rude architectural-looking piles, 300 or 400 feet high, and two or three miles inland from the summit of the scarp, so that this much must be added to the 3,400 feet, to make up the total height of the table-land. The height of the scarp was obtained by triangulation from a base measured on Marbat Plain, from whence the real summit of the table-land could not be seen; we had no means of obtaining these heights in any other way.

The soil on the summit of the table-land is of a brick-red colour, and more or less argillaceous; it seems to come from the cavities and disintegration of the limestone, which, where it is bare, has been weathered into sharp undulating ridges, as it is on some parts of the coast, where the action of the sea is producing the same effect.

The following are the fossils which were obtained from these limestone strata:—

FORAMINIFERA.

Alveolina sphæroidea, H. J. C.—Ovo-spheroidal or melanoid; long diameter $\frac{6}{36}$ inch, short diameter $\frac{5}{36}$ inch. Sulcated longitudinally, in sigmoid lines, which extend from apex to apex, marking the divisions of the chambers, which present transverse parallel striæ, dividing them into compartments. *Loc.*—Marbat, from the summit of the formation inland downwards to an unknown extent.

Obs. This fossil varies in size below the measurement given. It is a characteristic fossil, and occurs also in great abundance in Lower Sinde, near Tatta, where it is well known by the name of "Tomra," and forms the sacred strings of beads worn round the neck by Hindu devotees, and others of that religion. It differs from *Fasciolites elliptica*, Sow. (Grant's Geology of Cutch, pl. xxiv. fig. 17, which, on the other hand, abounds in the hills of Hyderabad in Sinde), in being more spheroidal, and exceeds a little in size the largest of those I met with at Marbat.

Alveolina Melo, D'Orbig.

Operculina, D'Orbig.—*Species ?* Discoidal, nautiloid, very thin. Width $\frac{5}{24}$ inch. Surface presenting four whorls, divided into many chambers, which are reflected, and increase regularly from the first to the last cell. *Loc.*—White limestone, Marbat.

Obs. This little fossil frequently accompanies *Alveolina sphæroidea*.

Cyclolina Arabica, H. J. C.—Circular, concave, extremely thin in the centre, abruptly expanding into a thickened rim at the circumference. Diameter 1 inch, thickness at the rim $\frac{1}{12}$ inch. Surfaces smooth, presenting a series of concentric rings, alternately raised and

depressed. Internally composed of minute cells, arranged in concentric circles, which are multiplied vertically to four or five tiers deep, as they extend from the centre to the circumference. *Loc.*—Marbat.

Obs. This fossil is present in the rock specimens from the summit of the white limestone strata, and varies in size below the measurement given. It is a characteristic fossil of this series, and extends down to the coloured division, where it is found among strata almost entirely composed of a much smaller fossil of the same kind, as we shall see hereafter. The *Alveolina* and *Operculina* above described are also found in company with this large *Cyclolina*. A species also occurs in great abundance in the Hala Mountains, near the Buran River, in Sinde, together with the spheroidal *Alveolina* called "Tomra" above mentioned, and an *Operculina*; all three appear to agree with the three as they are found together in Arabia as to outward appearance, but the internal structure of the first and last slightly differs. The cells appear larger in the *Cyclolina* of Sinde, and the whorls more numerous in the Sinde *Operculina*. (For further remarks see this Vol. p. 550.)

Corbis ?—*Species ?* (Shell, imperfect.) Breadth $3\frac{9}{12}$ inches, length $3\frac{4}{12}$ inches. Cancellated; resembling *Corbis pectunculus* (Lamarck, et Tab. 13, figs. 3—6, Paris Basin, Deshayes.) *Loc.*—Marbat.

Obs. Found in a small block of fine white compact limestone, with individuals of the foregoing fossils.

Inoceramus ?—*Species ?* (Specimen imperfect.) Shell thin, suborbicular. Length $2\frac{1}{4}$ inches, breadth 2 inches. Inequilateral, striated concentrically, cardinal edge of upper valve straight. *Loc.*—Marbat.

Obs. Found in the block of limestone just mentioned.

GASTEROPODA.

Nerita.—*Species ?* (Specimen imperfect.) Shell thin, suborbicular, subspiral, involute, with an ill-defined apex. Length $2\frac{1}{4}$ inches, breadth $1\frac{3}{4}$ inch, and thickness $\frac{3}{4}$ inch. *Loc.*—Marbat.

Obs. Found together with the foregoing fossils. Species of this genus are very common in Sinde, and almost all that I have seen from thence, which, like the present, are chiefly reduced to their casts, have been more or less filled with *Fasciolites elliptica* and the spheroidal *Alveolina* above mentioned. They range from one to four inches long, with proportionate height, and have thc border of the columella denticulated.

Carinaria ?—*Species ?* Conical, reflected. Length $\frac{11}{12}$ inch, breadth at the base $\frac{4}{12}$ inch, slightly compressed laterally, striated horizontally, with a ridge or raphe in front. *Loc.*—Marbat.

Obs. Found with the foregoing fossils.

Trochus.—*Species ?* (Cast, imperfect.) Height about 4 inches, and

breadth at the base 4 inches. Spire consisting of nine or ten whorls. *Loc.*—Marbat. Found with the foregoing fossils.

Buccinum.—*Species ?* (Cast, imperfect.) Length 2¾ inches, breadth 1½ inch. *Loc.*—Marbat.

Obs. Found with the foregoing fossils, which were also accompanied by casts of olives, but too imperfect for description.

From the coloured agillaceous strata I obtained nothing but a rock-specimen of limestone of a lead-blue colour, almost entirely composed of a small piece of *Orbitolina*, D'Orbigny, such as we shall find by-and-bye at Ras Fartak, but I did not preserve it, not knowing at the time from what part of the series it came.

Nor did I see anything in the micaceous sandstone worth noting, except a tessellated arrangement of a stratum in the lower part, over which the path passed, leading from Marbat to the base of the table-land. It is on the short plain here which extends outwards from the base of the latter to the border of the torrent bed, and is raised about 30 feet above the level of the sea. At first I thought this was the tiled surface of a floor belonging to some old building, but a few moments' reflection and observation convinced me that it was the cracked surface of the stratum, which must have been formed at the time of its deposit. The cracks had been an inch wide, and had been filled up with a dark ferruginous sand, which contrasted strongly in colour with the white coarse-grained quartziferous sand of the stratum generally, and therefore of those parts which it surrounded. This ferruginous deposit, or cement, had cracked again in its centre, and so the whole of the divisions had become more or less loose and separable. They are, of course, of various sizes, and of all kinds of polygonal shapes, and about three inches thick: the ferruginous sand not only coats their sides, but their lower surfaces as well, and it is probably owing to the presence of the iron that this remarkable feature has been preserved. It shows us plainly that this part in particular of the sandstone must have been deposited at the level of the sea, where the tide now and then overflowed it (for no cracking could take place under the sea), and that too before the 4,000 feet of strata now above it were deposited; and, as the uppermost stratum of the latter contains the remains of animals which must have been deposited in the sea, these cracks further show that this portion of the sandstone must have gone down at least 4,000 feet since they were formed, and have returned to a position higher than that even in which it was first deposited. I took particular care to ascertain the correctness of this by observations made on the spot, and brought away some of the loosened divisions for closer examination; and the total absence of calcareous material in them, connected with their containing particles of mica, and being of the same composition as the sandstone in which

they are found, at once places beyond doubt the possibility of their being a subsequent formation. Neither can these divisions, or the sandstone in which they exist, be confounded with any other above it, because there is no other above it so coarse; and if it had been a portion of the same sandstone disintegrated and re-deposited, it must have contained more or less particles of carbonate of lime, from the detritus of the older rocks, and the sea in which it was re-deposited; for every formation which has taken place subsequently to, above, or alongside this sandstone does contain more or less calcareous material.

I had not time to examine these sandstone strata much, or probably I might have met with some fossils in them.

Having, then, seen the igneous tract at Marbat, and traced the strata of the table-land to its summit, let us now return for a few moments to the granite plain, where we shall find a modern formation, well worthy of our attention, and which we shall have to trace on for some distance, and identify with similar ones which we have passed, for it will be some way before we can again get a section of the table-land; and in the mean time we must occupy ourselves with the no less important deposits which lie along its base.

Capping the plain of Marbat, the highest part of which, I have before stated, is about 30 feet above the level of the sea, is a granular deposit, composed chiefly of particles of carbonate of lime, with which are mixed more or less grains of quartz and hornblende, from the igneous rocks on which it reposes. It is about a yard in thickness, and extends in all directions over the plain to within a mile of the sea. It contains a great number of organic remains, consisting chiefly of casts of small bivalves. This, indeed, is the fossil character of the deposit. The houses at Marbat are built with it, and some of the headstones of the graves there are made from slabs of it, which will show that it is of considerable consistence. It fills the inland extremities and crevices of the fissures, which I have stated to extend through this plain to the sea, and there contains very large perfect shells; and adherent to the side of the group of granite hills at the bottom of the bay is a large mass of it, the upper part of which is 30 feet above the level of the sea. Here it presents a vast quantity of corals, with large shells of Hippopus, Ostrea, &c. All these shells have lost their animal matter, and are more or less friable and pulverulent. This formation in its more subtle material closely corresponds with the miliolitic deposit at Ras Abu Ashrin, and when we have proceeded a little onwards from the igneous rocks, we shall find its composition and appearance to be almost identical with it; while at Marbat it more resembles that part of the miliolitic deposit which we have seen resting on the dioritic rocks, near the village of Gyren, in the island of Masira; it is, in fact, again the Miliolitic Formation.

Between the Miliolite and the water's edge is a coarser deposit, which overlaps the former, and is composed of rounded gravel from the granite rocks, held together by a whiter matrix than that of the foregoing deposit; and, still nearer the sea, a third, still more white, and apparently more recent, the upper surface of which is about 12 feet above the level of high-water-mark.

The fossils obtained from these deposits were :—

Lucina ?— (Cast.) Breadth 1 inch, height 1 inch. *Loc.*—Marbat, in the miliolitic deposit lying on the granite plain.

Obs. There were many other bivalves present, smaller than this, but none so numerous.

Venus.—*V. puerpera vel corbis* (Lam.) *mihi.* (Specimen imperfect.) Breadth 3 inches, height 3 inches. Cancellated, the lines projecting a little at their points of decussation. *Loc.*—Marbat, in the deposit between the latter and the water's edge.

Ostrea.—*Species ?* Inferior valve oval. Length 8 inches, breadth 5 inches. Deep, patulous; muscular impression subcentral, lateral; straight posteriorly, convex anteriorly. Impression of hinge concave, rhomboidal, wavy, terminated by a straight border anteriorly, and by an ill-defined one posteriorly. Margin crenulated for a short distance on each side the hinge; afterwards simple, wavy. Upper valve thin anteriorly, thickened posteriorly, with a deep angular longitudinal groove in the centre. *Loc.*—Marbat, from the miliolitic deposit at the end of a fissure in the granite plain.

Up to this I have said nothing of the remains of another formation here, which is seen on the inner side of the group of granite hills next the base of the table-land. It forms part of a deposit on the granite plain prior to the Miliolite, and is better seen a little further on, for here it only peeps above the sand close to the sea, or exists in remnants at the part I have mentioned. The part close to the sea consists of a coarse cellular limestone, in which are sparsely scattered rounded portions of hyaline quartz, and particles of other minerals from the igneous rocks, together with a few remnants of small fossilised shells. Its colour, which is of a dark brown, like that of moist brown sugar, as well as its appearance, at once characterizes it among the other deposits, and not less so the extreme craggedness into which it wears by the action of the waves. It is sometimes saccharoid, and generally effervesces slowly with acids. The parts further inland on the granite consist of coarse yellow limestone and gypsum.

With this description of what we shall hereafter find to be the shattered remains of the little Nummulitic Series, let us proceed along the coast; and, leaving the granite hills of Marbat, we cross the bed of the torrent mentioned to the base of the great slope of the table-land, following

which for four miles over a narrow plain between it and the beach, partly covered by drift-sand, we at length arrive at an abrupt elevation presenting a sea-cliff 100 feet above the level of the sea. This cliff, from the summit of which a level plain extends back for about half a mile to the base of the great coast escarpment of the land, is continued on, broken through here and there by torrent beds, to the village of Takah, about twelve miles distant. Four miles west of Marbat I examined it, and afterwards a large rock of it, called the island of Guena, which is of the same height, close to the cliff. The geological section of both, from above downwards, is the same, and therefore the latter is but a detached portion of the former; it is as follows:—

	Ft.
Calcareous sandy deposit, like the miliolite mentioned, in which are imbedded rounded pebbles of the older limestone	5
Compact, coarse, shelly, impure limestone, of a light whitish colour.	
Dark brown limestone, of the kind stated to exist behind the granite hills at Marbat.	
Compact white limestone, breaking with a conchoidal fracture and even surface.	

The brown limestone here is more saccharoid in its structure than at Marbat, and contains a little magnesia; in its upper part is sparingly scattered small rounded quartz gravel from the igneous rocks, and below it presents white spots, which are but large pebbles of compact limestone, from the older formation, now almost indistinguishably blended with it.

When we approach the end of this cliff, which is at Takah, we might expect, as it appears all of the same height, to find all the same strata again, but this is not the case, for the Miliolite is absent, probably has been swept off by denudation, and the cliff, by measurement only 91 feet high, much thrown forward, and the strata sloping at an angle of 30° towards the sea, which is their general inclination throughout this escarpment.

The white shelly limestone, however, appears here again on the top in thick strata, compact in some parts, cretaceous in others, and richly charged with *Orbitolites Mantelli*, H. J. C.; *Orbitoides Prattii*; and *Orbitoides dispansus*, H. J. C.; with the endless varieties in figure of the former, and that foliaceous expansion of the same structure which so often accompanies these fossils in Sinde; for a description of all of which, see the foregoing paper on the Larger Foraminifera of Sinde. Besides these fossils, the blocks which had fallen forward from the overhanging cliff appeared to be almost entirely composed of different kinds of corals; and below the whole came the dark-grey brown limestone, first seen at Marbat.

Orbitolina pleurocentralis, H. J. C. Elliptical, thin, flat, wavy. Surfaces presenting a corresponding prominence on each side, situated laterally and towards one end of the ellipse, covered with minute tubercles, which, becoming larger excentrically, pass off into moniliform rows, that, after a subspiral course, terminate on the margin. Internally consisting of a single plane of oblong chambers filling up the intervals between the rows of tubercles, with their long axes horizontal and across their spiral course. Margin inflated, round, smooth, without apertures. Length of largest specimen 7-24ths inch, breadth 5-24ths inch, thickness at the prominence a little more than at the margin, which is 1-60th inch. *Loc.*—Takah.

Obs. This beautiful little, pearl-white fossil abounds among the *Orbitoides* and *Orbitolites* just mentioned. It bears the same relation in point of simplicity of structure to *Orbitoides*, that *Operculina* bears to *Nummulina*. It also closely resembles, in the section and contour, fig. 2 *c* of Lamarck's *Orbiculina adunca* (Tabl. Encyclopéd. et Méthod. pl. 468). Should we choose to assimilate this fossil to *Operculina*, we have only to draw an *Operculina* with three or four whorls and reflected chambers on a piece of paper, and then join the septal divisions of each whorl together, and strengthen these lines while we lighten that of the spire; the spire dividing the whorls will then represent the septa in *Orbiculina*, and the septa, being joined end to end in *Operculina*, will represent the lines of tubercles in *Orbiculina*. A vertical section through the long axis of this fossil shows that the short part, behind the prominence, is thin at the margin, while the margin of the long part, or that in front of the prominence, is inflated.

Orbiculina mammillata, H. J. C. Circular (?), equally thin with the foregoing, but with the prominence in the middle (?) surmounted by a large smooth tubercle, around which are a number of minute ones which become doubled and trebled with the increase of their distance from the centre, at last forming short, straight lines, which, being alternate in adjoining rows, thus pursue a ziz-zag, subspiral course to terminate in the margin, like the rows of tubercles in the last species; but here the tubercles are situated over the septa, instead of over the lines which run between the rows of chambers (I term the long sides of the chambers the septa). Chambers oblong, quadrangular, where largest twice as long as they are broad, in fact, the same as in the last species, and only one layer deep. Margin, round (?), thin, not inflated. Diameter 2-12ths inch. *Loc.*—Takah, in company with the other Foraminifera just mentioned.

Obs. Having only met with one specimen of this beautiful little fossil I do not like to risk taking it out of the matrix for further description. It still more approaches the central plane of *Orbitoides* than the last, in

the border not being inflated and the surface markings not being much elevated.

The authors of the Foss. Num. de l'Inde have asked in their "Table," p. 361, if the *Orbitolites* above mentioned be the "species of the United States?"—in reply to which I can only observe, that it agrees strictly with the characters of "*Orbitoides Mantelli*" given by Dr. Carpenter in the Quarterly Journal of the Geological Society of London, vol. vi. pl. vi. figs. 20, 21, and pl. vii. fig. 31, viz. in presenting, on a horizontal section of the central plane, *circular cells* having apparently a "*concentric*" (p. 32, *id.*) arrangement; and in a vertical section quadrangular cells in the central plane, and compressed cells above and below it; hence the cells of the central plane must be cylindrical, while the variety of shapes which this fossil may assume, from the variable thickness of the mass of compressed cells, gives it at one time a plane and at another a raised surface in the centre. These characters are also presented by the other specimen which I have described and figured (Ann. and Mag. Nat. Hist. vol. xi. p. 175, and pl. vii. figs. 40 and 41, respectively), and which the authors to whom I have above alluded have conjectured to be *Orbitoides* (p. 350, *op. cit.*). But how can either of these species be *Orbitoides,* when the central plane of this fossil is composed of *oblong* chambers, arranged in *subspiral* lines running off from a centre, with their *long axes horizontally?*—unless the opposite to these characters be deemed insufficient for a generic distinction, and a "considerable" elevation of the disc "diminishing gradually towards its margin," as Dr. Carpenter has remarked in his "Monograph on the Genus *Orbitolites*" (Philosophical Transactions, 1856, p. 195), be regarded as decisive. Still this will not be sufficient, for many varieties of this fossil do not present any elevation at all, being perfectly flat and square at the ends in a vertical section, like some of the fossils to which Dr. Carpenter has, I think, rightly restricted the term *Orbitolites.* At the same time the fossils which I have described under the head of "*Orbitolites*" are so distinct from those described under that of "*Orbitoides*" (Ann. and Mag. Nat. Hist. *loc. cit.*), that I cannot see how the two are to be included in the same genus. The respective characters of the central planes of *Orbitoides* and *Orbitolites* are given in figs. 35 and 36, pl. vii. (*Id.*; *id.*), and the other differences mentioned in the text.

I am by no means certain, however, that the cells of which the central portion of *Orbitolites Mantelli,* H. J. C., is composed have a concentric arrangement; and if this should not be the case, but they come off subspirally, as the chambers of the central plane of *Orbitoides,* then it seems to me not improbable that these subspiral rows of cells may issue from a spiral line twisted round the vertical axis of the fossil, after the manner of the rows of cells in *Orbitolites Malabarica,* H. J. C. (Ann. and Mag. Nat. Hist. vol. ii. p. 425, 1835), which I now find to be so closely allied in structure to *Orbiculina angulata,* Lam. (Tab. Encyclopéd. et Méthod. t. iii. pl. 468, fig. 3), that its place seems to be under this genus rather than *Orbitolites,* Lam.:—but *Orbiculina pleurocentralis,* H. J. C., has no marginal pores any more than Lamarck's *O. adunca* (*loc. cit.*), while his *Orbitolites,* which Dr. Carpenter has very properly taken as his type of this genus has; so here again adjustment seems to be necessary.

Hence then, if the structure of *O. Malabarica* should be the same as that of the centre of *Orbitolites Mantelli,* H. J. C., we should have *O. Malabarica* bearing a similar relation to *Orbitolites Mantelli,* H. J. C., that *Orbiculina* above described bears to the central plane of *Orbitoides,* and *Operculina* to that of *Nummulina;* but the arrangement of the cells, forming the centre of *Orbitolites Mantelli,* H. J. C., has yet to be discovered; it evidently consists of a plurality, but whether they come off spirally from a vertical axis or not, I have, up to this time, been unable to determine; a "concentric" arrangement would be more a character of *Orbitolites,* Lamarck, than of *Orbitoides,* D'Orbigny.

The end of the cliff at Takah has evidently undergone much disturbance, from the great square blocks of it which have fallen forward into the sea, while the rents in the plain between this and the base of

the table-land, a distance of about two miles, bear ample testimony of the distorting forces to which this locality has been subjected.

In this cliff, then, we have evident signs of the Nummulitic Formation, at the same time that we have been able to trace it on uninterruptedly for twelve miles, lying at the base of the inclination extending from the summit of the great table-land here to the sea; and, as remnants of it were seen still further back on the granitic plain of Marbat, it will be as well, before going further, to tabulate the stràta that have come under our observation between Marbat and Takah, as this is about the centre of the south-east coast of Arabia. Thus we have :—

Great scarp of the coast.	White limestone strata above, containing *Cyclolina* at the summit, which, according to A. d'Orbigny, is confined to the Cretaceous Series. Coloured argillaceous strata. Micaceous sandstone, of great thickness.
Low cliff between Marbat and Takah.	Miliolite. White shelly limestone, charged with Foraminifera, belonging to the Nummulitic Series.

At Takah, as just mentioned, the sea-cliff ends, and the maritime plain between the base of the high land and the sea sinks from 100 to about 10 feet above the latter; it also expands westward from this point, for the mountains recede and give place to a flat area, twenty-two miles long, and from ten to fifteen miles deep in the centre: this is called Dofar, and is the most fertile district on the coast. Over this plain is spread a continuation of the Miliolite which we have seen capping the plain at Marbat, and the low cliff just passed, but it is more uniform in its composition, and more free from dark particles of the igneous rocks; hence it closely resembles the Miliolite at Ras Abu Ashrin. On it are the remains of several towns, one of which, called El Bălăd, I have described.* They were built of this freestone, and they contain a vast number of columns, ornamented in arabesque, which have nearly lost their figured surfaces where exposed to the weather. This deposit seems to average about 10 or 12 feet in depth: In many parts of it there are extensive fissures, or *khors* as they are locally called, some close to the beach, which are always full to the brim of fresh water; that, for instance, at El Bălăd is more than two miles long, and in one part about 100 yards broad, and flows over the beach, though no stream can be seen running into it. It is the presence of these *khors*, and the looseness of the soil, which render Dofar so fertile in comparison with the rest of the coast.

Passing along the cord, or sea shore of this half-moon-shaped plain, we at length arrive at its opposite or western extremity, where the high

* Journal Royal Geograph. Soc. vol. vi. Trans. Bombay Geograph. Soc. vol. vii.

land, as at Takah, comes out again to within nearly the same distance of the sea; we also find this end of the plain elevated again to about the same height as at Takah, and consequently a sea-cliff in front of it, which presents a similar geological section to the Nummulitic Strata (for such we will now call them) composing this cliff four miles west of Marbat; commencing from above, it is as follows:—

	Ft.
About a mile inland from the summit of the cliff, limestone gravel and pieces of flint, imbedded in red argillaceous earth, and capped by five feet of limestone pebbles and flints of a large kind, with less red earth, probably fluvial	55
White shelly limestone	20
Impure limestone, composed chiefly of small rounded gravel from the older limestone, mixed with a quantity of red argillaceous earth, giving the stratum a red colour	7
Limestone of a greenish, reddish, dirty white colour; shelly, with radiated masses of columnar coral, and a great number of casts of smallish bivalve shells (Conchacea et Ostrea)	7
Bed of large oysters	1½
Dark brown limestone first seen beside the granite hills at Marbat, close to the sea, presenting in its upper part a stratum, 2½ feet thick, of large rounded pebbles; these pebbles are of compact white limestone, and are from the older formations	10½
White compact limestone, of a fine structure and breaking with a conchoidal fracture, at high-water-mark or a little lower.	

This forms the section of the cliff, and against the upper part of the dark brown limestone and lower white shelly limestone rests the Miliolitic Deposit of Dofar, six or eight feet above high-water-mark, filling many holes in the former, which have been made by lithodomous animals, and containing oysters of the same kind as those of a bed close by.

I have stated that the mountains advance towards the coast here, but the coast-line also turns here from running east and west, to south, and then south-east, a little way before it resumes its original direction; that is, it is reflected to form a little bay here, called the Bay of Resut; and hence the maritime lowland, which is narrowed at this end of Dofar, is widened again, not in this instance by the mountains receding from the shore, but by an advancement of the lowland upon the sea, and with this advancement the lowland also is bordered externally by a ridge, which in one part is 700 feet high, and scarped upon the sea throughout. Thus, then, we have a valley between the sea-cliff of this ridge and the mountains; a small promontory formed by the end of the ridge, called Ras Resut, and inside it the bay mentioned of the same name. Now into this bay we have the opening of a torrent bed a mile wide, coming not only from the valley itself, but from among the

mountains, and the section of the cliff just given is taken from the inner corner of the opening of this torrent bed upon the sea. This, then, accounts for the additional "fluvial" strata of red earth, flints, and pebbles, before mentioned, and which we did not see in the section taken four miles west of Marbat, where the cliff is within two miles of the base of the mountains, and on a straight part of the coast, far removed from the influence of any great torrent deposit. We, therefore, must not include in this littoral deposit this 55 feet of red earth, pebbles, &c., because it is evidently a local accumulation, while the Miliolite is seen attached to the upper part of the brown limestone in the scarp of the cliff.

Passing across the sandy beach, which lies in front, and which, in the dry weather, closes the mouth of this torrent bed, we arrive at its opposite or external corner, which is close to the base of the ridge mentioned, and that of the small promontory which shelters the bay. This corner, like the other, presents a low cliff consisting of little more than the dark brown limestone we saw on the other side, and which, running along the base of the promontory parallel to the sea, and scarped upon it for about eight feet, is washed by the waves into that extreme cragginess so characteristic of the stratum in other parts. This deposit rises no higher, while the height of the promontory is 200 or 300 feet above the sea at its base, and 200 at its extremity. Here then, we have compact white limestone raised up to form the ridge of the promontory, while the Nummulitic Series is thinned out to the dark brown limestone only, which remains in a horizontal line at its base. Nothing, therefore, now can be more plain than that this white compact limestone, which we have seen all along underlying the dark brown limestone, is a part of the cretaceous series, or that of the great white limestone series of the table-land. One more remark I would make here, viz. that, whereas gypsum has always appeared in the lower or arenaceous part of the nummulitic series at Măskat, Masira, and Marbat, where this series has been deposited on, and subsequently raised up with igneous rocks, no gypsum was observed in it between Marbat and Ras Resut, where it has been deposited on limestone. Perhaps the emanation of sulphureous fumes from the igneous rocks in the former localities may account for this difference, which, easily passing through the arenaceous deposits, would meet the calcareous infiltrations from the superincumbent limestone just where the veins of gypsum are situated.

From Ras Resut, which at its extremity is about 200 feet high, a sea-cliff is continued on for twenty-three miles, to the base of the great promontory called Ras Sejăr, which is formed by the advancement of the mountainous tract upon the sea. This cliff I had not an opportunity of examining much, as it is perpendicular, and rises directly out of the water. What I did observe, however, is interesting.

I have just stated that there is an entire absence of igneous rocks at Resut, but, though this is the case, they are not far distant, one would think, for not only the limestone of the cape is shivered into atoms, and rendered pink by heat, but, six miles further on, the base of the cliff is similarly fractured where it is 700 feet high. This point is called Ras Hammar, and is the maximum altitude of the cliff. Ras Hammar is composed of compact white limestone above, and of the comminutely fractured limestone mentioned below, but I am ignorant of what lies between, further than that the whole is white calcareous strata, and that among these there are some of a marly cretaceous nature, from which the Bedouins cut their pipes, similar to that at Marbat. The brecciated limestone, for such it is, from the crevices having been filled up by a cement, and that too of the same material, is of a dense compact fine structure, lithographic, but breaking with a splintery fracture, heavy and hard, and of a light grey colour. By a rough analysis, it contains from 12 to 15 per cent. of magnesia. Its specific gravity is 3·3. It scarcely effervesces with acids until pulverized, and its great weight and hardness appear to be owing to the presence of silex.

In this limestone is a cavern, similar to those which abound in the mountains, and one of which I visited near Takah. Its base is just above high-water-mark, and its roof is about 30 feet high, and hung with stalactites, not of magnesian limestone, but of sulphate of lime. From the face of the cliff presenting innumerable excavations of lithodomous animals, on a parallel with the upper part of the roof, and the brecciated state of the limestone, it is probable that this cavern commenced with the latter, and was subsequently washed out by the waves, while the cliff was rising from the sea. That which I visited, near Takah, is in the mountains, and I have given a description of it in this Journal.* It was inhabited, and is about 150 feet span and 50 feet high (not yards, as stated from oversight in the description to which I have referred), and 30 yards deep. Its roof is also smoothed, and hung with thick stalactites : another cavern, of equal dimensions, close by, had fallen in. We saw some from the vessel in the elevated scarps of the mountains in different localities, which, judging from the size they appeared at the distance we were from them, must be of enormous dimensions. They form the principal habitations of the Bedouins of these parts, and descend from father to son as hereditary property.

From Ras Hammar we pass along the remaining part of this cliff to the base of Ras Sejăr, which it joins after a distance of twenty-five miles from Ras Resut, diminishing gradually in height after Ras Hammar, until it arrives at this point. Ras Sejăr is the largest and highest promontory on this coast : it is an advancement upon the sea of the

* Journ. Bombay Br. Royal Asiatic Society, vol. iii. No. xiv. p. 253.

great mountainous tract which from this point south-westwards, for a distance of sixty miles, presents no maritime plain whatever, but descends directly to the sea in long slopes or in precipitous steps. The ridge of the promontory has been computed by trigonometrical measurement to be 3,380 feet above the level of the sea, and the bluff at its extremity 2,770 feet. The eastern side is scarped perpendicularly for 800 feet, and the strata, which are composed of white and grey limestone, are disposed horizontally.

At one part of the talus of this cliff is a little island presenting remnants of the Nummulitic Series, among which is the brown limestone characteristic of the lower part, and a finer kind corresponding to that which is so richly charged with *Orbitoides*, &c. at Takah, but here replaced by innumerable species of Lamarck's genus *Orbitolites*, such as have been figured by Dr. Carpenter in his valuable Monograph on this genus, *loc. cit.* The Miliolite is also seen here, but much finer in structure than it is at Dofar. After this I did not recognise the brown limestone, though doubtlessly it or its representative exists here and there throughout this coast.

The south-eastern side of Ras Sejăr, which is parallel with the coast, and its south-western extremity, the highest point of the cape, present an almost vertical scarp, in which the strata are seen to dip towards the north-east; while on the south-western side, the same horizontality is seen which we observed on the eastern side, but with a scarp rising by high precipices and narrow shelves to the ridge of the promontory, which I have before stated to be 3,380 feet above the level of the sea. At the point where the coast line turns from running NE. and SW. to about NW., for a short distance, is the great bluff of Ras Sejăr, and the following appears to be its geological section, from above downwards:—

	Ft.
White limestone strata	2570 (?)
Argillaceous strata, of different colours, principally red, containing many fossils	175
Fine-grained micaceous sandstone or quartzite, of a bluish-grey colour, thinly stratified, and breaking with a rough fracture across the planes of stratification ; it is weathered into holes indicative of the presence of organic remains, and in some parts veined with white quartz ; hardly differing, except in colour, from the upper part of the micaceous sandstone at Marbat. Concealed at the base by the sea	25

Having at the foot of this section measured with my eye, as carefully as I could, the height of the lower projection of the bluff above the sea, for I had no means of obtaining it in any other way, I find, when I come to multiply this on the outlines of the bluff, which I made at different distances, that the latter does not amount to more than 1,950

feet above the sea, which is 820 feet less than it was computed to be by trigonometrical measurement; possibly, and not improbably, from the place where the base was measured, the angle was taken from a point much higher than the summit of the real bluff. The height of the limestone bluff at the island of Hăllăniyah being 1,645 feet, and the estimated thickness of the limestone at Marbat about 1,800 feet, together with the trigonometrical measurement of the scarp of the next promontory we shall come to, which is limestone from the water's edge to its summit, being 1,900 feet, seems also to indicate, from the thickness of the limestone at these places, that my measurement of the bluff at Ras Sejăr is more correct than that obtained by triangulation, but probably from the reason above mentioned.

I collected no fossils from Ras Sejăr, beyond some small imperfect specimens of the genus Turritella (?) from the coloured strata towards its base, for the sea was so rough, and the scarp so perpendicular and without talus, that we could only remain there a few moments.

It is to the blue-grey sandstone of this promontory that the late Captain Newbold alluded when hinting at the origin of the quartzite pebbles in the conglomerate, underlying the Nummulitic Strata at Măskat and resting on the euphotide and diorite of that locality.* A little further in from the extremity of Ras Sejăr on the south-west side, where the precipitous part of the promontory is much higher than at the cape, this sandstone is also raised to 300 feet above the level of the sea; and my impression is that here, as well as at Marbat, its strata are not parallel with those immediately overlying them, but dip towards the north; still I am far from being certain that this is the case.

As on the other parts of the coast, so on the lower part of Ras Sejăr, there is a thick line of the Miliolite adhering to the side of the cliff, 150 to 200 feet above the level of the sea. On the south-western side of the promontory I think I also saw it again, reaching down to the water, for there are dwellings excavated there, in a yellowish white deposit, which can only be this or the micaceous sandstone, while it is not likely to be the latter, from its hardness and dark colour here. At all events, it exists again at Rakot, a little village at the mouth of a ravine-like valley, seven miles to the westward of Ras Sejăr. Here it is of considerable height and thickness, and of a finer structure than any on the coast. While I was knocking off some specimens, the Bedouins who were with me asked me if I wanted any *khat*, which means "white writing chalk," because, if I did, it was to be found in the upper part of Ras Sejăr. From this it would appear that the strata are chalky there.

Between the lastnamed village and a town called Damkot, some miles further on, are more dwellings, close to the sea, at the bottom of

* Journal Bombay Asiatic Society, vol. iii. part 2, p. 27.

the slope of the high land. These also appear to be cut out of the Miliolite: the place is called Jādăb. The high land also presents a more extended tabular outline here than hitherto met with, and continues to do so on to the neighbourhood of Damkot, forty-five miles from Ras Sejăr, where it becomes broken and thrown up into mountainous peaks again, the summits of which are about 3,000 feet above the sea. This form of the coast continues on for some distance, viz. to the opening of a valley called Shagot, where the coast-line turns to the south, and the scarped mountainous ridge, here precipitous upon the sea, pursues its original course south-west, under the name of the Fattak range. A lowland shore, therefore, commences at this point, which, as the coast trends southward, is continued on till it meets the lower hills of a mountainous ridge called the Fartak range, a distance of forty miles, and from it, between these two points, viz. the Fattak and the Fartak ranges, it extends inland or south-westward as far as the eye can reach; it is the only part of this coast where the mountain ridges which face the south-east appear to be separated by any great interval. The sea-cliff of this lowland varies with the height of the lowland itself, but seldom reaches 100 feet. I had an opportunity of examining it about its centre, where its cliff is 60 feet high, and the following is the section from above downwards :—

	Ft.
Coarse subcellular shelly limestone, breaking with a rough fracture; of a light brown or yellowish colour, mottled red below................	6
Chalky argillaceous strata, presenting faint impressions of shells; of red, white, and yellow colours intermixed, but chiefly red above and white below, where it becomes concealed by the beach..................	54

Here also, 15 feet above high-water mark, is a line of the Miliolitic Deposit, adhering to the side of the cliff, and composed of the calcareous sandy material before noticed, in which are imbedded a number of shells.

There is a pebbly beach at this place, composed of rounded pieces of more or less compact limestone, and concretionary flints; also here and there a large piece of extremely fine limestone, of a lithographic structure, from one to three feet in diameter, apparently the altered remains of fossilized madrepore, and perhaps the hardened portions of the chalky strata. I saw no pebbles or traces of igneous rocks here; indeed, this part of the coast seems to have undergone less disturbance than any other, although the line of Miliolite shows that, like the rest, it is experiencing gradual elevation.

The cliff of which this is a section is more or less continuous from this point on to the lower hills of the Fartak range, which commences in an angle close to the sea. One side of it runs inland and south-west-

wards, which is the grand direction of the range, and the other southwards, to end in the cape called Ras Fartak. This angle is about fourteen miles from the cape. Here the strata of the lowland cliff also become elevated, broken up, and confused, and this confusion extends to within six miles of the cape, where the irregularity ceases, and the uppermost stratum of the great white limestone series can be seen emerging from the water, and gradually pursuing its ascending course to the top of the escarpment, which is 1,900 feet above the level of the sea, after which it assumes a horizontal direction, and continues on to the summit of the cape: in this way stratum after stratum of this series may be seen rising from beneath the water, until the lowest runs almost parallel with it; so that no better place could be visited than this for examining deliberately and without interruption the strata of which this limestone formation is composed. I had only an opportunity of visiting one part of it, and this was where the strata had become horizontal, and where a portion of the face of the cliff having fallen off, enabled me to obtain from the talus thus formed a knowledge to a good extent of the lower part of it. It consists of more or less compact, more or less cavernous, and more or less subsaccharoid white limestone, which again is more or less mottled, or rather veined with dark brown subsaccharoid magnesian limestone. I saw no traces of fossils in it, except a few minute species of Foraminifera, of the genus *Alveolina* (D'Orbigny). In one part the rock is entirely saccharoid, sparkling, uniform in structure, and of a grey colour, in fact dolomitic, and on a rough analysis yields 16·4 per cent. of magnesia, with a specific gravity of 3·07. It is an interesting fact, bearing, perhaps, upon the formation of dolomite, that the dark veined portions here are of magnesian limestone, effervescing feebly with acids, while the whiter portions bubble up as usual when touched with them.

As we approach this extremity of the Fartak range, which forms the cape called Ras Fartak, and which is also the south-western limit of the great bay of El Kammar, a reddish tint makes its appearance at the base of the cliff, close to the water, and on turning the corner we observe, by the truncated end of the cape, that this is the commencement of the argillaceous strata, which, rising towards the west at an angle of 45°, reach an altitude of from 1,000 to 1,200 feet on the opposite side of the ridge, at the same time that they crop out so much as to extend the base nearly a mile beyond the summit of this promontory. To the geological section of this series let us now turn our attention, having considered that of the white limestone strata which lie above and behind it, on the eastern side of the cape. Commencing from the summit of this advanced portion, then, and proceeding downwards, we find the following section,—which was obtained by examining the base of the cape

from east to west, and noting down the characters of the strata as they emerge successively from the sea:—

	Ft.
Fine compact limestone, of a light violet colour, breaking with a smooth conchoidal fracture, containing small *Orbitolinæ*, and other fossils	300
A wide stratum of a red, argillaceous limestone, presenting the same kind of fossils, in greater number, with echinodermata	50
Greenish-yellow, argillo-calcareous strata, splitting into thin laminæ, on which are seen the remains of a few minute bivalve shells, and marks similar to those made on mud by small crabs and annelides..........	20
Red, ferruginous, argillaceous limestone, followed by a stratum of a bluish-grey, argillo-calcareous, siliceous shale, exhibiting, where exposed to the atmosphere, a jointed structure and thick laminæ..............	10
Blue marl, compact above and soft below, in which are remains of Echinodermata, Ostracea of the genus *Exogyra*, and pyrites	30
Impure limestone, compact, and of a pinkish-grey colour, the lowest hundred feet of which (the only part I examined) is almost wholly composed of small *Orbitolinæ* with the remains of a few small echinodermata....	300
Impure limestone, compact, and of a dark red colour and ferruginous aspect; fossiliferous, and abounding in large cavities and fissures, which appear to have been caused by some subterranean force; rock shattered throughout, and cemented together again by its own material	500

The sixth is the last stratum towards the west which emerges from the sea: it is opposite the little village of Khaisêt. After this, the remaining part of the extremity of the Cape is confronted, by a narrow sandy beach, from beneath and behind which the coloured strata continue to rise in the same manner as from the sea, to the extent mentioned.

Among the more thinly stratified deposits of the upper part of these coloured strata are bands of brighter colours, which have not been mentioned: these consist of much the same kind of material as that with which they are in contact, or form a part, and give to the whole a variegated appearance when near, but, when viewed at a distance, are lost in the prevailing red colour of this series.

The following are the fossils which I gathered from these strata here and at Ras Sharwên, the next large cape, which is sixty miles further west, but a part of the same formation:—

ZOOPHYTA.

Astrea.—*A. textilis*, Goldf. (Tab. 23, fig. 3), *mihi*. Hemispheric, covered with conical projections, which are more prominent in the upper part than towards the base; and marked with striæ, which radiate from their summits. Horizontal diameter $\frac{8}{12}$ inch. *Loc.*—Ras Fartak, from the pinkish-grey limestone.

Orbitolina patula, H. J. C. Conical, obtuse, excavated, patulous, slightly

recurved at the margin. Breadth $\frac{2}{12}$ inch, height $\frac{1}{20}$ inch. External surface presenting concentric rings; internal surface presenting striæ radiating from the centre to the circumference. Structure solid, composed of minute reticulated cells. *Loc.*—Ras Fartak, chiefly in the pinkish-grey limestone.

Variety? Conical, acute, deeply excavated. Breadth $\frac{1}{8}$ inch, height $\frac{1}{20}$ inch.

Variety? Flat, circular, wavy, thick; diminishing in thickness towards the circumference. Breadth $\frac{3}{12}$ inch, thickness $\frac{1}{32}$ inch.

Variety or *Cyclolina?* Discoidal, flat, thin. Breadth $\frac{8}{12}$ inch. External surface presenting smooth elevations in concentric rings. *Loc.*—Upper red stratum, Ras Fartak.

Obs. The structure of all the small specimens is the same. Concentric lines, beginning at the apex of the cone externally, extend to the margin; these are a little closer towards the apex than towards the circumference where they present distinct perpendicular partitions irregularly alternating with each other in adjoining rows of cells, while, towards the apex, this defined structure becomes reticulated. Internally sinuous lines radiate from the centre to the circumference, where they appear to correspond to the partitions between the outermost circles of cells. This fossil differs, therefore, from D'Orbigny's *Cyclolina*, which exists in the superincumbent white limestone, and may be present among the small fossils under description, for I saw much larger ones than those described, which, indeed, I thought were *Cyclolinæ*, but the clay being wet in which they were imbedded, I could not preserve any of them. Throughout the white limestone small thin fossils of this description abound, but it is only in this part of the series that they are so remarkably multiplied as to demand particular attention. At first I called them *Orbitolites*, but a more minute examination points out that they belong to D'Orbigny's genus *Orbitolina*, which is exceedingly interesting, because they are confined, according to this distinguished paleontologist, like *Cyclolina*, to the Cretaceous Series. (For a more particular description of this *Orbitolina* see p. 549.)

ECHINODERMATA.

Spatangus.—1st *Species?* (Spec. imperfect.) Oval. Length nearly $1\frac{1}{2}$ inch, breadth anteriorly $1\frac{1}{2}$ inch. Truncated posteriorly, slightly grooved anteriorly, ridged posteriorly. Ambulacra five, subpetaloid, all the same length, in deep furrows. Vent subdorsal. Base imperfect. *Loc.*—Ras Sharwên.

——— 2nd *Species?* Thick, round, heart-shaped. Length $1\frac{3}{4}$ inch, breadth anteriorly $1\frac{6}{12}$ inch, and height 1 inch. Grooved antero-dorsally. Ambulacra five, two anterior shortest. Buccal orifice sub-

terminal, simple. Base not carinated. Vent subdorsal. Genital pores four. *Loc. idem.*

Obs. There is another specimen similar to this, and from the same locality, $1\frac{1}{2}$ inch long.

Spatangus.—3rd *Species?* Thick, round, heart-shaped, like the foregoing, but much smaller. Length $\frac{11}{12}$ inch, breadth anteriorly $\frac{10}{12}$ inch, and height $\frac{6}{12}$ inch. *Loc. idem.*

Discoidea, (Gr.)—1st *Species?* Subpentagonal, excavated. Breadth 2 inches, height 1 inch. Ambulacra extending to the buccal orifice, which is median. Vent submarginal, pear-shaped, convex posteriorly. Genital pores five. *Loc.*—Ras Sharwên.

——— 2nd *Species?* Conical, circular, elongated towards the apex, which is acute. Breadth $1\frac{7}{12}$ inch, height $\frac{9}{12}$ inch. Ambulacra, buccal orifice, vent, and genital pores the same as in the foregoing. *Loc. idem.*

——— 3rd *Species?* Subpentagonal, conical. Breadth $1\frac{1}{3}$ inch, height $\frac{8}{12}$ inch. Buccal orifice, vent, &c. the same as in the foregoing species. *Loc. idem.*

——— 4th *Species?* Subpentagonal, convex. Breadth $1\frac{4}{12}$ inch, height $\frac{5}{12}$ inch. Buccal orifice, vent, &c. the same as in the foregoing species. *Loc. idem.*

——— 5th *Species?* Conical. Breadth $1\frac{1}{2}$ inch, height $\frac{8}{12}$ inch. Vent submarginal, longitudinal, pointed at each extremity. Buccal orifice, pores, &c. as in the foregoing species. *Loc. idem.*

——— 6th *Species?* Circular, convex. Breadth $1\frac{4}{12}$ inch, height $\frac{5}{12}$ inch. Buccal orifice, vent, genital pores, &c. the same as in the last. *Loc. idem.*

——— 7th *Species?* Circular, depressed. Breadth $1\frac{4}{12}$ inch, height $\frac{5}{12}$ inch. Buccal orifice, vent, genital pores, &c. the same as in the two last species. *Loc. idem.*

Pygaster, (Ag.)—*Species?* (Specimen imperfect.) Small, circular, thick, convex. Breadth $\frac{7}{12}$ inch, height $\frac{9}{24}$ inch. Slightly excavated. Ambulacra five, narrow, extending to the buccal orifice, each presenting a double row of small tubercles. Inter-ambulacral spaces furnished with a double row of large tubercles, each tubercle sunk within an elevated ring, and the latter bordered on both sides by a small circle of tubercles. Buccal orifice median. Vent pear-shaped, margino-dorsal, longitudinal, round posteriorly. Genital pores five. *Loc.*—Ras Fartak.

Echinus.—1st *Species?* Circular, depressed, slightly excavated, Breadth $1\frac{4}{12}$ inch, height $\frac{6}{12}$ inch. Tubercles small throughout. Ambulacra narrow, and extending to the buccal orifice, which is median; their extremities widely separated at the vent, which is medio-dorsal. *Loc. idem.*

Echinus.—2nd *Species?* (Spec. imperfeet.) Hemispherie, circular. Breadth $1\frac{1}{12}$ inch, height $\frac{11}{12}$ inch. Tubercles small throughout. Ambulacra five, rather broad, bordered by four lines, or two double series of pores, extending to the buccal orifice, which is median; their extremities widely separated at the vent, which is medio-dorsal. *Loc. idem.*

Diadema, (Gr.)—1st *Species ?* Circular, depressed, slightly excavated. Breadth $1\frac{1}{2}$ inch, height $\frac{1}{2}$ inch. Tubercles small, perforated. Ambulacra bordered on each side by four lines of pores, extending to the buccal orifice, which is large and median ; their extremities widely separated at the vent, whieh is medio-dorsal. Vent broken. *Loc. idem.*

——— 2nd *Species ?* Circular, depressed, slightly excavated. Breadth $1\frac{1}{4}$ inch, height $\frac{5}{12}$ inch. Tubercles large, perforated, almost all of the same size, subequidistant, and in vertical lines. Ambulacra bordered by two lines of pores, sinuous, extending to the buccal orifice, which is large and median, and widely separated at the vent, which is medio-dorsal. Vent broken. *Loc. idem.*

Salenia, (Gr. et Ag.)—1st *Species ?* Circular, thick, convex. Breadth $1\frac{1}{12}$ inch, height $\frac{8}{12}$ inch. Two vertical lines of large tubercles in each inter-ambulacral space, four tubercles in each line, imperforate. *Loc. idem.* Found in the pinkish-grey limestone.

——— 2nd *Species ?* Circular, thick, convex. Breadth $\frac{10}{12}$ inch, height $\frac{1}{2}$ inch. Two vertical lines of large tubercles in each ambulaeral space, four tubercles in each line. *Loc. idem.*

Obs. The only difference which I can distinguish between these two specimens, excepting in size, is that the plate resting on the dorsal extremity of the ambulacral space is concave in the centre in the latter species, and pointed in the former one. For a further description of Salenia, see Monographies d'Echinodermes, par Louis Agassiz, 1838 ; and for the genital plates of these two species see Tab. 1, figs. 1 and 22, respectively. The specimens above noticed are much worn and imperfect.

——— 3rd *Species ?* Smaller than the foregoing, circular, compressed. Breadth $\frac{8}{12}$ inch, height $\frac{5}{12}$ inch. Three large tubercles in each line. Resembles the last specimen described in the form of its genital plates. *Loc. idem.*

Conchifera.

Tubicola.—*Species ?* Tube cordiform, or subcircular, simple ; smooth internally, crenulated externally ; dilating gradually from a small orifiec to $\frac{6}{12}$ inch in diameter, and then expanding suddenly. Wall composed of successive additions, imbricated ; internally presenting minute parallel longitudinal lines, running throughout. *Loc.*—Ras Fartak, in the dark red ferruginous limestone ; in plurality, *en masse*, in different directions.

Obs. A transverse section of the dilated part gives a deep crenulated margin, presenting angular costæ and circular intervals, within which are several layers of the same form (10 — 12), and white lines radiating from the internal margin, which is even, to the circumference. These are the lines which appear longitudinally on the inner side of the tube. Tubes 3 to 4 inches long.

Isocardium.—1st *Species ?* (Cast.) Breadth $2\frac{5}{12}$ inches, height $2\frac{1}{2}$ inches, and depth $2\frac{5}{12}$ inches. Umbos $\frac{2}{12}$ inch apart. *Loc.*—Ras Sharwên.

——— 2nd *Species ?* (Cast.) Breadth $1\frac{1}{2}$ inch, depth $1\frac{1}{4}$ inch, height a little greater than the breadth. Presenting thin striæ on the surface. *Loc. idem.*

——— 3rd *Species ?* (Cast.) Breadth $1\frac{2}{12}$ inch, depth 1 inch. Smooth. *Loc idem.*

——— 4th *Species ?* (Cast.) Breadth $\frac{10}{12}$ inch, height $\frac{10}{12}$ inch. *Loc. idem.*

Plagiostoma, *mihi.*—1st *Species ?* Inferior valve only. Narrow, compressed above posteriorly. Breadth $\frac{13}{24}$ inch, height $\frac{9}{12}$ inch, depth $\frac{3}{12}$ inch. 6-costate including the two lateral ones, costæ consisting of one broad and two narrow ridges, and the intervals filled up with two broader ones ; margin obsoletely hexangular ; no alæ, no spines ; yet this fossil very much resembles *Janira atava* (D'Orbigny's Cours Elément. de Paléon. &c. t. ii. fac. ii. p. 601. *Loc. idem.*

——— 2nd *Species ?* Inferior valve only, imperfect. Broader than the last. Breadth 1 inch, height $1\frac{3}{4}$ inch. Sub-6-costate, ridges uniform, without spines. Margin subhexangular. Subalate. *Loc. idem.*

Pecten.—*Species ?* Inferior valve only. Breadth $\frac{17}{24}$ inch, height $\frac{9}{12}$ inch, and depth $\frac{2}{12}$ inch. 6-costate, a single wide ridge forming the prominent ribs, and two smaller ones occupying the intervals. Margin hexangular, deeply toothed. Uni-auriculate or inequi-auriculate (?). At first sight this shell is very like *Pecten quinquicostatus*, Sow. *Loc.*—Ras Fartak.

Ostrea.—*Species ?* (Lower valve, imperfect.) Ovato-acuminated. Plicated, plaits radiating from an indistinct sharp umbo ; striated concentrically, striæ lamellose, and imbricated towards the border, the latter crenulated. Length $3\frac{1}{2}$ inches, breadth $1\frac{1}{2}$ inch. *Loc. idem.*

Exogyra.— *E. flabellata*, Goldf. (Tab. 87, Fig. 6), *mihi. Loc. idem.* Fartak.

Obs. These abound in the blue marly stratum, and are of various sizes. The largest found is $2\frac{3}{4}$ inches long, and $2\frac{1}{4}$ broad, and the smallest 1 inch long, and of proportionate breadth.

GASTEROPODA.

Solarium.— *Species ?* Breadth $\frac{1}{12}$ inch. *Loc.*—Ras Fartak, in the deep red ferruginous limestone.

Turritella.— 1st *Species ?* Slender. Length $1\frac{1}{4}$ inch. Whorls 12. 10 — 11 costæ in each whorl. *Loc.*—Ras Fartak, red ferruginous limestone.

Turritella.—2nd *Species ?* Slender. Length $1\frac{1}{4}$ inch. Whorls 18 — 20, three costæ in each whorl. *Loc. idem.*

Ammonites.—*Species ?* A small portion of the whorl, $\frac{11}{12}$ inch wide; just enough to show that the suture is sinuous. *Loc.*—Ras Sharwên.

Thus we see that the advanced or lower half of Ras Fartak is composed of marls, clays, sandy shales, and impure limestone strata, containing the above fossils, and of a variety of colours, but principally red, terminating above in violet-coloured and almost white limestone. We have also seen, when facing this cape, that the strata of the range, of which it is the extremity, dip from west to east as at Ras Sejăr, and that the uppermost of the red or coloured series, which is not more than 200 feet above the level of the sea on the east, is 1,000 to 1,200 feet above it on the west side of the cape. Passing on to the white limestone above and behind these strata, we find the latter denuded for some distance in from their upper edge, both on their southern and western sides, and not continuous with the white strata, as at Ras Sejăr and at Marbat. This denudation of the upper part of the coloured strata, and position of the white limestone series, I could not understand, until, from my sketches of the cape on different sides, I perceived that the strata, both white and red, of the range, dipped not only towards the east, but towards the north. We have already seen them at the extremity of the cape dipping from west to east. Hence, when we come to connect the inclination of all these strata with the existence of an argillaceous deposit about their centre, we cannot be surprised to find that the upper half has slid down towards the north-east, and left the whole of the lower or coloured strata in the advanced way mentioned; which not only accounts for our not seeing the red strata at the bottom of the great scarp, that faces the eastern side of the range, towards the Bay of El Kammar, but also for the presence of the sub-range of mountains which exists on its western side.

Difficult as it would have been to have joined these two series with the absence of the micaceous sandstone, and to have accounted for their relative position at this point, without having seen the inclination of the strata, yet the existence of *Cyclolina* in the white limestone at Marbat, and its presence in the coloured strata here, together with the finding of a piece of blue limestone at Marbat, almost entirely composed of small *Orbitolina*, and identical with the pinkish-grey limestone of the same

kind here, at once connects the two, identifies the coloured strata of both places, and establishes the position of the latter at Ras Fartak.

It is remarkable, however, that the coloured series should be so thickened here, and that the micaceous sandstone should not appear.

Thus we see that there are 1,900 feet of white limestone strata in the cliff on the eastern side of the Fartak range, and from 1,000 to 1,200 feet of coloured strata forming the advanced part of the cape, and that of the western side of the range. The additional height, therefore, of the main ridge, which has been computed by triangulation to be 2,500 feet above the sea, must be accounted for by the inclination of the strata; for although the base of the white limestone is about the level of the sea on its eastern side, it must nevertheless, from the dip of the strata in this direction, be elevated for some hundreds of feet above the sea, where it rests on the coloured strata on the western side of the range.

Before leaving Ras Fartak, I should state that the pinkish-grey limestone, which is filled with *Orbitolina*, and which rises from the sea just opposite the little village of Khaisêt, is perforated by the holes of lithodomous animals, 30 feet above the level of the sea, and adherent to its side at the same height is a band of the Miliolite mentioned, containing shells which are in a white pulverulent state, and pieces of the adjoining rocks. This deposit, though not very compact, is sufficiently tenacious to form a building stone, of which the little tower now in ruins on the top of this limestone, which forms a conical hill here, was composed.

From Ras Fartak south-westwards, the coast line forms an obtuse angle with that just passed, and for some distance presents no cliff, but a low sandy shore, reaching back to that part of the Fartak range, which I have before stated to run south-west. This sandy shore, which reaches inland for about six miles, continues along the coast for twenty-five miles, when it is limited by a tract of low rocky limestone mountains, which begin on the sea at a cape called Ras Darjah, about 300 feet high, close to which is a cliff composed from above downwards, as follows:—

Pink, grey, white, and yellow compact limestone, in parallel strata from three to twelve feet thick respectively, with here and there large round concretionary flints, peeling off in concentric layers. Some of the strata are friable, loose, and gritty, not unlike those at Hammar el Nafur and Ras Kariat, and in like manner containing a great number of small Echinodermata of the following kind:—

Echinocyamus Annonii, Mirian (?).. (Tab. 27, figs. 37—40. Ag. Mon. d'Echinodermes.) Length $\frac{11}{24}$ inch, breadth $\frac{10}{24}$ inch, and thickness $\frac{3}{24}$ inch. Vent a little distance from the margin, not quite so far as that of *E. Annonii*. *Loc.*—Ras Darjah.

E. alpinus, Ag., *mihi*. (Tab. 27, figs. 41—43. *Loc. cit.*) Length $\frac{8}{24}$ inch, breadth $\frac{8}{24}$ inch, and thickness $\frac{3}{24}$ inch. Vent infra-marginal. *Loc. idem.*

Obs. Of this fossil Agassiz states, p. 135: "Mais ce qui rend surtout cette espèce intéressante, c'est son gisement. Je n'en connais que deux exemplaires qui font partie du Musée de Berne; ils ont été recueillis dans la chaîne des Alpes Suisses, à Burgenberg, près Stanz (canton d'Unterwalden), dans une sorte de conglomérat fossilifère noir appartenant au terrain crétacé, et contenant une quantité de fossils triturés, entre autres une grande nummulite." This remark is not less interesting here, where we find these little fossils in a similar deposit to that which exists at Hammar el Nafur and Ras Kariat, and which contains the same kind of fossils with nummulites; from which we might perhaps infer, if I am right in the identification of the species, that the cliff at Ras Darjah belongs to the same formation as that at Hammar el Nafur and Ras Kariat.

This group of rocks, and the sea-cliff which they present, do not extend far from Ras Darjah before they diminish in height, and become covered with a plain of yellow sand, of four or five miles in extent. The sand appears to be nothing more than a disintegrated part of the Miliolitic Deposit before mentioned, which here has been raised on the tops of the rocks, on which it was deposited, and, like that at Ras Abu Ashrin, has become loose on the surface, and now forms a smooth uneven tract, which, in its irregularities, correspond to those of the harder rocks beneath. It presents a sea-scarp of about 30 to 40 feet high, and ends at the little plain of Kishn; after crossing which we arrive at the mountainous tract again, which now advances to form the cape called Ras Sharwên.

This cape consists of a long narrow mountain, of a wedge-like shape sloping towards the point, and presenting on its upper end two gigantic pillars of limestone close together, one of the natural wonders of the coast: it is about two miles long, and scarped on both sides, as well as at the extremity; the latter at its lowest point is about 200 feet above the level of the sea, and the top of the pinnacles about 1,800 feet. Its longitudinal direction is about east and west, so that its inner face is opposite the main land, and it shelters a little bay inside it, which is called the Bay of Kishn. This mountain is composed of coloured strata, identical with those which form the advanced part of Ras Fartak, and in like manner seems to have been denuded of the white limestone; but what has become of the latter, the land above water does not indicate; no doubt this wedge-shaped mountain was covered by it, as the next mountain to it inland presents the white limestone *in situ*. I might here content myself with referring the reader to the description of the coloured

strata at Ras Fartak, for those of Ras Sharwên, as I have placed the list of fossils from both places after the former, but it will be more satisfactory, perhaps, to give the observations which were made on the spot respecting their composition.

About a quarter of a mile inside the cape, where we landed, the upper part, which is not very high here, is composed of fine compact limestone, of a white or light grey colour, presenting small *Orbitolinæ* and a few remains of echinodermata. This, after some distance down, passes into a violet, and then red-coloured argillaceous limestone, containing a great number of the same kind of fossils, together with bivalve and univalve shells; after which comes a yellow stratum, with blue and red bands intermixed, and then a blue deposit, almost entirely composed of small *Orbitolinæ* like the pinkish-grey limestone at Ras Fartak. The whole of these coloured strata contain more or less argillaceous matter and siliceous sand. A little further in, where the red-coloured ferruginous strata emerge from the water, the same shattered appearance of the limestone is seen as at Ras Fartak, with calc-spar coating and more or less filling its cavities.

Here, too, on the inner side of the cape, as on the pinkish-grey limestone at Fartak, is seen a band of the Miliolite adhering to the scarp 40 feet above the level of the sea, and containing in some parts, as at Fartak, large shells, and portions of the adjoining rock; while between its lower part and the sea there is, as at other places, an interval of some yards, where it either never existed, or has been washed off by the waves.

Having finished with the inner side of Ras Sharwên, let us now go to the outer side of the cape, and here, too, a mile or two west of the latter, the red strata are again seen, but in the utmost confusion. This is owing to a mass of black scoriaceous basalt, which has forced itself up among them; and although it has not managed to reach the surface, yet, from being in the sea-cliff, a good lateral view is seen of it. It is about 300 or 400 yards long, and about 200 feet high. I had hunted in vain for a disturbing agent of this kind at Ras Fartak, and on the inner side of Ras Sharwên, but could see nothing *in situ* at either, though, from the presence of pebbles of scoriaceous black basalt about the base of the latter, I was led to infer that it could not be far distant.

This is the first place where we have seen an igneous rock since leaving Marbat Plain, a distance of 200 miles, and the first time we have met with black basalt on the coast; but we shall soon see that we have come to the commencement of a series of vents, which have poured forth large tracts of this igneous rock.

As we saw a raised sandy plain of the Miliolitic Deposit covering the low rocks east of Kishn, so we have a similar one west of Sharwên. It is coarser in structure than the Miliolite of Ras Abu Ashrin, but

otherwise almost identical with it. It begins close to the western side of the black basalt, which indeed it partly covers, and extends a short distance inland, and about ten miles along the sea, where it present a cliff about 100 feet high. As before stated, it is raised, and, though smooth on the surface, takes the form of the harder and older rocks which lie beneath, while the presence of particles of basalt in it would seem to indicate that it has been formed since the eruption of that rock.

Leaving Ras Sharwên, and this tract of sand, the limestone formation continues to rise abruptly from the sea for twenty miles, when it falls back, and leaves a narrow strip of maritime plain, which is continued all the way to Ras Makalla (a distance of 140 miles), backed from one end to the other by the raised tract of limestone mentioned,—sometimes in the shape of peaked mountains, at others in that of long portions of table-land; while extending along this narrow plain is the series of basaltic effusions to which I have alluded.

These commence immediately west of the opening of the great valley called Wadi Masilah, and about twenty miles from the beginning of the maritime plain, or forty miles from Ras Sharwên. They are three in number, and are called by the Arabs the "Harieq," or "Burnt Place," from a superstition that they mark the sites of seven pagan cities, which were burnt down by the Imam Ali at the commencement of the Mahomedan æra. They form the most remarkable objects of the kind on this coast, and are continued on to a little beyond the village of Raidah, a distance of forty-five miles from their commencement. Their striking features are their intense black colour, their flatness, and horizontal extent, defined borders, and the contrast they form with the white colour of the plain, and that of the limestone mountains behind them. Each tract presents one or more cones in the centre, which do not appear to be more than 200 feet above the basalt immediately surrounding them.

The first cone is about four miles from Saihut, or about 50 miles west of Ras Sharwên, and the tract of basalt which surrounds it has extended nearly to Wadi Masilah on the east, and joins the following tract on the west.

The next cone is opposite the opening of the valley called Wadi Shikawi, about nine miles from the last, and about three miles inland: its tract extends westward to Raidah, a distance of about eighteen miles, and eastward joins that of the foregoing, as already mentioned. I examined a part of this tract opposite the valley of Shikawi, where it extends into the sea, and its highest part, not including the cone, did not appear to be more than 30 feet above the level of the sea. The whole of the maritime plain here is covered with large and small boulders of black and grey basalt, more or less compact, more or less

scoriaceous, breaking with a rough coarse fracture, and presenting olivine in its cavities. Some pebbles which I picked up on the beach were composed of fine compact basalt, in which distinct crystals of pinkish-white felspar were imbedded. All the boulders were weathered smooth, and more or less round.

The third tract begins west of Raidah, and here the maritime plain, being raised from 200 to 300 feet above the level of the sea, the basalt has not only overflowed it, but found its way into the water-courses, and appears in black rocks at their openings on the beach, contrasting strongly with the whiteness of the low limestone cliffs on each side of them. There are five cones in the centre of this effusion, which are all higher, I think, than either of those mentioned.

Here also the maritime plain widens out to an extent of fifteen miles between the base of the high land and the sea, and, being raised, presents a low cliff generally, but which, at the cape called Ras Bu Gashwa, is 300 feet high, from which it diminishes gradually on either side for a few miles, until it subsides to the level of the beach. There are several portions of this part of the plain raised in isolated mounds 700 or 800 feet high, and the whole seems to have undergone much disturbance from subterranean causes : the district is called Hamman, from the number of hot springs here. I had not an opportunity of going on shore, so I can say nothing of the sea-cliff further than that above it looks red, in the middle white, and below yellow ; but we shall find it again at Makalla, and perhaps may be able to infer its geological character from the composition of the cliff at that place. It, however, looks very much like a return again of the little Nummulitic Series.

I have before stated that this maritime plain ends at Ras Makalla, to which we now arrive, and on turning which we observe that it consists of a ridge of igneous rocks, supporting limestone. This ridge presents an irregular scarp upon the sea of two and a half miles in extent on its western side, and on its eastern side limits the maritime plain we have just left.

When we examine it from within outwards, that is from its inland base to its sea-extremity, we find that it is made up successively of granite, limestone, and green serpentiniferous diorite.

The granite is part of a group of bare, igneous rocks, which extend a little further inland, but appears here capped with limestone, the summit of which is 1,300 feet above the level of the sea ; that of the granite appears to be about 1,000 feet. It is of a dark grey colour, and uniform fine structure, and, from its amphibolic admixture and freshness, seems more allied to sienite or diorite than old grey granite. Be this as it may, it is diked with the green, earthy diorite of the locality, and, suddenly sinking towards the cape, disappears in low peaks beneath the limestone,

while the latter then forms the body of the promontory for some distance, and is about 600 feet high. After this follows the green diorite bared of the limestone in round topped hills, which thus compose the outer third of the cape, still diminishing in height, but supporting an isolated portion of the limestone again between them, a little distance from the extremity. The diorite presents an earthy base of a greenish colour, with crystals of dark green hornblende scattered through it; it is richly serpentiniferous, and sometimes appears like green euphotide. Where it forms a breccia with the limestone of the locality, the calc-spar cement which binds the pieces together is tinged grass-green, apparently by chrome from the serpentine.

The limestone strata, which appear to be between 300 and 400 feet thick, are, in the immediate vicinity of the granite, fractured throughout, and united again by their own material, so that all appearance of continuity in their stratification has been destroyed; but in the cliff which they present in the middle third of the cape, and which is about 250 feet high, they are entire, and composed as follows from above downwards, viz.:—

Compact cellular limestone, of a pink colour, presenting in one part a stratum filled with the moulds of small shells, in which there is more or less crystallized gypsum.

Siliceous limestone, filled with large cavities lined with hyaline quartz and calcedony.

White stratum of more or less impure siliciferous limestone.

Dark red-coloured deposit, chiefly composed of fine siliceous sand, which rests on the granite.

The "cellular limestone" effervesces slowly with acids, and is identical, as before stated, with that sent me by Lieutenant Grieve from Ras Markas, near Ras Jazirăh, that is, as far as structure and mineralogical characters are concerned.

Although there are no separate fossils here, the upper strata abound in traces of them, and in some parts they are almost entirely composed of small foraminifera, allied to Nummulina.* In another part of the

* This is a Nummulina, agreeing closely with the description of *N. Lucasana*, Def. (Foss. Num. de l'Inde, p. 125, and fig. 8, pl. vii.), but not sufficiently so to make it the same species. Having only obtained one perfect specimen, which was weathered out from the mass, I am unable to state more of it than that which follows:—

Nummulina.—*Species?* Discoidal, rather thick than thin, margin rather thick than thin. Surfaces presenting a number of minute tubercles, grouped towards the centre, from which delicate, curved lines pass off towards the circumference, approaching which they become more prominent and surmounted by minute tubercles. Whorls 5, as counted from a vertical section; chambers narrow, reflected, numerous. The latter character was obtained from sections of fragments apparently of the same species in the same mass. Largest specimen 2-10ths inch in diameter, thickness in the centre 1-16th inch. *Loc.*—Makalla.

limestone formation close to the granite rocks, but not in contact with them, or forming part of the ridge of the cape, small foraminifera also abound, as at Măskat, and particularly the *Operculina* of that locality. I did not see any large nummulites, but I think it will hereafter be found that they are not more a character of the Nummulitic Series than the abundance of small foraminifera which exist in the limestone strata belonging to it, and indeed of which many of these strata are, with the addition of microscopic species, almost entirely composed.

We cannot help noticing here also the deposition of this series on igneous rocks, and the presence of gypsum in the cavities of the limestone, which throughout presents a pink colour,—probably produced by the heat of subsequent intrusions during its elevation.

Besides this limestone, we have here again the Miliolitic Deposit, forming in one part a bank 30 feet above the level of the sea, and in another adhering to the upper part of the scarp of the limestone cliff, extending to the cape from 60 to 100 feet above the level of the sea; while we have blocks of it on the shore on the inner side of Makalla, which have fallen down from the limestone on the top of the granite, 1,300 feet above the level of the sea, slightly changed in structure, but still easily recognizable, and of a delicate colour, like that of the pink or cream-coloured limestone in the same situation. The coarseness of the structure of these deposits at their three different heights, and the shells, pieces of coral, and parts of the old limestone rock which they contain, together with their modern appearance generally, indicate that they all belong to the same formation; but there is one difference, independent of the changes produced by heat, in the pieces which have fallen from the limestone on the top of the granite, viz. that it does not, like the other two, present portions of the green diorite. Thus it must have been raised up with the other limestone rocks before the elevation of the diorite took place, or all traces of particles of the latter must have been subsequently effaced. Still this does not interfere with the fact that this formation, which we have hitherto seen raised only 150 feet above the sea, viz. at Ras Sejăr, is here in one part 30, in another from 60 to 100, and in a third 1,300 feet above its level, and in the last place so changed in colour, that however young it may be considered to be, it must have preceded the elevation of the granite, and that of the limestone on which it rests.

About three miles inland, north-east of Makalla, just at the outskirts of the group of igneous rocks which are continued into the formation of the cape, and among the lower hills of the great limestone tract, is a spring, from which the inhabitants of Makalla obtain their supply of water. This issues from a ravine situated among the lower limestone mountains of the table-land which are fractured and fissured in all direc-

tions, and cemented together again by their own substance, except in some places, where there are holes and caverns which have not been so filled up, and are more or less filled with water, both in the sides of and leading into the interior of the mountains. The water of the spring mentioned is somewhat above the temperature of the air, but without taste or smell: in its course along the ravine it passes through sand, which has more or less accumulated on its sides, and in this is a quantity of botryoidal, magnesian limestone. The spheroids are of different sizes, up to an inch in diameter, which is the measurement of the largest obtained. They are of a coarse structure, formed of concentric layers, and present a rough arenaceous exterior. Some appear as if they had been formed in halves, from the two hemispheres not having been applied to each other in complete apposition. They are more or less adherent, and seem as if they were formed in the sand of the stream in which they were found.

Among the igneous rocks at and in the immediate neighbourhood of Makalla, which form a varied and extensive group, exists a porphyry, with a dark red base, and large tabular crystals and nodules, of greenish felspar; also epidote with calc-spar, as at Masira. Mica prevails in some parts, and various other earthy minerals, which are generally found in company with such rocks.

Leaving Makalla, and proceeding south-westwards along the coast for about six miles, we meet with no sea-cliff whatever but a sandy shore, with scattered hills interiorly, and then sub-ranges of mountains; behind which, and towering above all, is the brink of the table-land (Cretaceous Series ?), here about 6,000 feet above the level of the sea.

At Ras Brum, however, which is at the termination of this sandy shore, and which is opposite Ras Makalla, as the coast runs, igneous rocks again make their appearance, and from thence are continued on to Ras el' Assidah, a distance of about fifty miles, after which they subside gradually in dark peaks, scattered here and there among the sand-hills of the coast.

This tract of igneous rocks fringes the shore for the distance mentioned, and is continued inland for two or three successive ranges, mixed more or less with limestone, to the base of the table-land, here fifteen miles from the sea. From their brown colour and peaked appearance they closely resemble the granite of Makalla; and about Ras Brum, before stated to be opposite Ras Makalla, is the same kind of green-coloured rock as that forming the outer third of the latter cape, viz. green diorite: at Ras Brum also it is in round-topped low hills like those of Ras Makalla, and separates the brown-peaked mountains behind, which are 1,000 feet high, from the sea. In all probability these rocks are but a repetition of those forming Ras Makalla, but at Makalla my actual

examinations cease, and I can only now state that which I have seen of this part of the coast while sailing leisurely up and down it two or three times, and from the sketches I then made of it.

I have observed that these rocks are more or less mixed up with limestone,—the limestone no doubt through which they have been forced,—so that here and there white ridges appear among the dark brown rocks, and occasionally come to the sea, as at Ras Răttle, which is a conspicuous white mass of limestone five miles east of Ras el' Assidah. The islands, too, off Hisn Ghorab, a little east of Ras Răttle, viz. Hăl-lani, Jibus, and Baragah, are all of white limestone. Jibus, which is perhaps the largest, is five miles off shore, hardly a mile long, and about 300 feet high.

A little west of Ras Brum there is a long low level piece of pink or red-coloured strata, bordering on the sea, and presenting a cliff similar to that of the raised part of the maritime plain at Ras Bu Gashwa; it is probably an undisturbed part of the same Nummulitic Formation, rendered red probably by heat, as that of Makalla.

The dark mound on shore, called Hisn Ghorab, famous for bearing the longest Hamyaritic Inscription that has been met with, is stated (Wellsted's Trav. in Arab. vol. ii. p. 423) to be composed of a dark greyish compact limestone, 500 feet high; and in further proof of the general elevation of this coast, which from what I have stated must now, however, be pretty apparent, it is also mentioned that "The action of the sea might be plainly seen [at the foot of this mound] in the cavities and hollows exhibited by a ridge of rocks now some distance from the water, but which evidently at some not very remote period must have been covered by it."

Between Ras el' Assidah and Aden, the coast is almost wholly unknown to me, except from a distance; there is no sea-cliff there, and not much on the maritime plain to interrupt the view from the sea to the base of the mountains after leaving the neighbourhood of Ras el' Assidah. About sixty miles north-east of Aden the high land advances to within a few hundred yards of the shore, and affords a grand view from its rapid and almost uninterrupted descent from three, four, and six thousand feet to the plain below. The sea too, just here, is vastly deep, and admits of close approach to the shore without danger.

Not more than twenty-five miles on from this, the seaward boundary of the mountains recedes from the direction of the coast, and stretching over to the Straits of Băb el Mandeb, ends in the south-western extremity of the great elevated tract of Southern Arabia, while the coast, continuing on in its original course some miles further, before it takes a similar turn, leaves a triangular plain, at the apex of which is the town of Aden, situated in the crater of an extinguished volcano, the

sides of which reach about 1,700 feet above the level of the sea. This crater opens towards the east, and presents a trail of peaks, ridges, and low cones, in the opposite direction, the whole of which amount to about six miles in extent.

I had not an opportunity of examining much of this mass of volcanic rocks, but I could see that they were principally composed of basalt pierced with dikes of the same material, in a more compact state. The external side of the crater is more or less scarped, and separated from the high peaks and ridges which flow from it, and in this scarped portion may be seen lines of horizontal stratification: also, some distance up the side of the slope which descends towards Back Bay, may be seen a small series of strata, consisting of pisolitic peperino, cemented together with glassy, crystallized gypsum, and from the manner in which the pieces of pumice, basalt, and obsidian of which it is composed are arranged, together with the fact of the cement being sulphate of lime, leaves no doubt that it was deposited in the sea, and afterwards raised to its present position; at one part it is at least 200 feet above the level of the sea, though it descends to the water's edge in another. The stratification of the walls of the crater, which is very high up, would also lead us to the conclusion that the greater part of this igneous mass has been poured out under the sea, and has been in turn gradually and paroxysmally raised to its present height.

Through the kindness of Dr. J. P. Malcolmson, whose name I have already had occasion to mention, and who resided at Aden for some time, I am in possession of specimens of all the rocks and minerals which this gentleman, after a long search, was enabled to collect; and, having been permitted to inspect his valuable assortment when at Aden, I am enabled to state that the igneous rocks of this peninsula consist of basalt in almost all its forms, compact, black, grey, peridotic; rough, cellular, scoriaceous, variolitic; tephrine, with small crystals of glassy felspar, which forms some of the high peaks in the interior of the crater; leucostine, which forms part of the lavigenous effusions in the north-west part of the peninsula, where the last vents of the volcano appear to have existed; pumite and stigmite, simple, variolitic, and pisolitic, which form small deposits in various parts of the general mass, and semiopal and calcedonies, which abound in the island of Sira, opposite the opening of the crater.* To these may be added brown carbonate of lime, in columnar stratified crystalline deposits, with transverse wavy lines; massive and fibrous gypsum; and fluor spar, in minute crystals of an amethystine colour, on the surface of calcedonies.

The recent littoral deposit here, as elsewhere on this coast, appears

* For the characters of the rocks here mentioned, see A. Brongniart's classification, Art. "Roches," Dict. des Sciences Naturelles.

in several parts of the north-west part of the peninsula, raised fifteen or more feet above the level of the sea.

About four miles west of Aden there is another group of volcanic rocks, said to be partly composed of granite, and their peaked forms would indicate this; it is about the same size as Aden. Last of all, on this coast comes the small dark group, probably also of igneous origin, which forms the eastern promontory of the Straits of Bāb el Mandeb.

Having thus come to the termination of the South-east Coast of Arabia, let us now pass over to the African Coast; and commencing from Berbera, which bears nearly due south of Aden, see if the rocks extending from this part eastward to Socotra have any resemblance to those on the coast we have just left.

Personally I know nothing of this coast, but Lieutenant Grieve, who surveyed a good part of it between Berbera and Guardafui, kindly collected specimens for me from the principal headlands between Berbera and Ras Sărai, and from all the islands excepting Socotra.

From these, and the observations which accompanied them, it appears that the top of the bluff at Syara, which is 300 feet high and about eighteen miles east of Berbera, is composed of a coarse heavy subsaccharoid magnesian limestone, effervescing very feebly with acids, and of a reddish colour and ferruginous aspect; while the base is composed of the same kind of rock, but of a greyish-brown colour: both are without any appearance of fossils.

The top of a hill on the coast seven miles further on is composed of a fine compact limestone, of a yellowish white colour, breaking with a smooth conchoidal fracture.

That of Hamarah bluff, which is 500 feet high, and twelve miles further on, of a fine compact subcellular limestone, of a cream colour, mottled with spots of red and white, with frosted cavities of calc-spar; also effervescing slowly with acids.

The top of Ras Khanzir, about 200 feet high, and seven miles further, of a fine compact limestone, of a yellowish colour, like that of the hill on the coast seven miles from Syara. Some portions appear, from their veined structure and opaque appearance, to have been exposed to volcanic influence. There is another portion from this cape, too, which, from its open structure and fossiliferous composition, is evidently of a later formation, and resembles much the modern deposit at Makalla. It has in like manner been exposed to heat, and its cavities and fossils are more or less soldered together by an amorphous white crystallisation of carbonate of lime.

The next specimen is from the hills near Ras Shalla, fifty miles further on. This is a compact limestone, of a pinkish colour, and uniform structure, breaking with an even granular fracture.

Hais Bluff, 500 feet high, and fifteen miles further on, affords a compact heavy limestone, of a granular sparkling structure, and a greyish brown colour. It is highly magnesian, scarcely effervesces with acids, and closely resembles that of the base of the white limestone cliff, on the east side of the Fartak range. Hais island, close to this bluff, is 300 feet high, and composed of a sparkling, black green amphibolite, fissile, laminated, and very much resembling gneiss, but serpentiniferous at the joints, and closely allied to the sparkling hornblende rock of Ras Jazirăh, on the South-east Coast of Arabia.

Meyt or Burnt Island, about twenty-six miles further on, and seven miles off shore, yields a pegmatite in composition, but not graphic in structure, and a compact limestone of a fine uniform saccharoid structure, and grey colour, effervescing feebly with acids. This yields by a rough analysis 15·32 per cent. of magnesia, and its specific gravity is 2·775: it is a dolomite.

In the museum of the Bombay Asiatic Society are specimens of limestone from Mărriyah, two hundred miles further east, and forty-five miles west of Guardafui. They were presented by Lieutenant Cruttenden, of the Indian Navy, and are of a cream colour, and compact fine structure, identical with the limestone on the top of the granite peaks at Makalla.

From this place we pass on to the islands between Cape Guardafui and Socotra, the first of which is Abd el Kuri, from which Lieutenant Grieve sent me specimens, as well as from the islands called Kal Farun, and "The Brothers," situated between it and Socotra.

The summit of Abd el Kuri is 1,600 feet high, and composed of a fine white compact limestone, breaking with a smooth conchoidal fracture, dry, and opaque, as if it had been exposed to heat; and the lower hills, which are from 200 to 400 feet high, yield grey and red granite, fine and coarse-grained diorite composed of black hornblende and whitish semitransparent felspar, ophiolitic diorite, and euphotide; indeed, all the kinds of igneous rocks that we have seen on the Arabian coast north of Marbat.

There is also a coarse, compact, subcellular, and subsaccharoid limestone, of a light cream colour, which comes from the higher parts of this island; it probably overlies the igneous rocks, and owes its colour to the action of heat; otherwise in structure it is just like the upper stratum of the low cliff in the Bay of El Kammar, and the dark brown limestone of the shores of Dofar.

The island of Kal Farun, fifteen miles north of Abd el Kuri, seems to be entirely composed of sulphate of lime. One specimen, coming from a height of 400 feet, is massive, compact, subsaccharoid, and of a brown colour; the other, which comes from high-water-mark, is earthy,

white, and contains moulds of small shells, with particles of igneous rocks.

Turning to "The Brothers," which lie between Abd el Kuri and Socotra, we find the largest, or westernmost of these two islands, to present pink granite rocks, 1,000 feet high, with limestone above them, reaching in all to 1,600 feet; also diorite, as at Abd el Kuri; and a white compact limestone conglomerate, raised 300 feet high. The latter consists of small rounded gravel, shells, and corals, which have been firmly cemented together, and more or less opalized, probably by heat; while the same kind of conglomerate, with a few particles of igneous rocks, exists at high-water-mark in the easternmost island, still possessing its original loose, dull, and recently-formed appearance.

Of Socotra I know nothing more than can be gleaned from the late Captain Wellsted's account of this island (Jour. Roy. Geograph. Soc. vol. v. 1835). In the vicinity of Tamarinda, a town situated towards the centre of the northern coast of the island, there are granite mountains, 5,000 feet high by measurement. "Connected with the granite range, and extending from north to south, a lower range is found, averaging in height about 1,900 feet, and composed of a compact cream-coloured primitive [?] limestone. From this the hills diverge in short ranges to the sea shore, their outline being mostly smooth, with table summits and rounded sides, except those nearest the sea, which mostly present a steep wall. The whole of the hills in the western part of the island are similar in their appearance, elevation, and construction."

In the neighbourhood of Goobet Koorma the limestone appeared to be borne up upon the granite, and the line of junction between the two was seen 3,000 feet above the place where Captain Wellsted stood.

Sienite, porphyry, and trap were seen in different parts of the island, and the soil of the mountains is clayey, stiff, and of a red colour.

Returning to the Somali coast, it is stated, that after a short but variable distance inshore, the land from Berbera to Cape Guardafui is raised to a height averaging between 4,000 and 7,000 feet, and attaining its maximum elevation midway between these two places. Lieutenant Speke informs me that he made the summit inland south of Bunder Ghoree about 7,500 feet by the thermometer. It is also said to be chiefly composed of limestone, and the specimens I have seen from it have been more or less fine and compact in structure, and of grey and white colours, similar in every respect to the limestone of the elevated tract on the South-east Coast of Arabia; while the cream-coloured limestone in like manner seems to come from the tops of the lower hills, where it is probably in closer proximity with the igneous rocks.

Thus we see that the same kind of igneous rocks, and the same kind

of limestones, exist on this part of the coast of Africa and its adjoining islands, that are found on the South-eastern Coast of Arabia and its adjoining islands; the same kinds of magnesian limestone, and a modern formation, corresponding to our Miliolitic Deposit.

There is also a spheroidal concretion of magnesian limestone, about the size of a walnut, which Lieutenant Grieve sent me from the coast of Africa, similar in every respect to that which has already been described as existing in the course of the hot spring near Makalla. I received no fossils; but a small collection from Berbera and its neighbourhood has since been sent to the Asiatic Society of Bombay by Captain Burton, part of which appear to belong to the Miliolitic Formation, and the rest to the Jurassic Series of Cutch. Thus we have among the latter,—

Belemnites canaliculatus, Schloth. (Grant, Geol. Cutch, pl. xxiii. figs. 2, 3; Trans. Geol. Soc. Lond. vol. v., and Pl. XVII. *id.* this vol.)

Terebratula intermedia, Sowerby (*id.* pl. xxii. fig. 10, and Pl. XVI. *id.* this vol.).

T. Microrhyncha, Sowerby (Colonel Sykes on Fossils of Cutch, pl. lxi. fig. 7, *id.* and Pl. XXI. *id.* this vol.)

Besides these there are several other terebratules, all of which, if not so much weathered, might find their identifications in figs. 13, 15, and 16 of the Cutch fossils (*loc. cit.*).

Arca (*species ?*).—Subtrigonal, much elongated posteriorly. Length 2 inches, width 1 inch. Ribbed and marked on the surface like *Cucullæa virgata*, Sow. (pl. xxii. fig. 1, *loc. cit.*), but by no means the same species.

Exogyra auricularia, Goldf. *mihi* (pl. 87, fig 2). Subsquare, 10-12ths inch broad and long, 6-12ths inch deep. Bearing the impression of part of a *Terebratula* to which it had been attached.

This concludes all that I have to offer on the geology of the North-east Coast of Arabia outside the Persian Gulf, the South-east Coast and its adjoining islands, and the Somali or North-eastern Coast of Africa and its adjoining islands. Let us now briefly review what has been stated respecting the South-east Coast of Arabia.

The first thing that strikes us here is the continuity of the white limestone formation, which we may reasonably infer to be the same from one end to the other, a distance of 1,125 miles; secondly, the eruption by elevation and outpouring of igneous rocks along the great line of fracture, or fault, which forms the coast; and, lastly, the elevation of the land from 4,000 to 6,000 feet above the level of the sea, which has brought into view other formations, lying beneath the white limestone.

Turning our attention, first, to the igneous rocks, we find that they comprise all the principal kinds, and probably most of the varieties,

included under this denomination; and that by far the greater part of them are hypogene (Lyell), the rest volcanic. The presence of gneissic strata in the granite at Marbat, also shows that some of this rock is at least secondary; and being mixed up with limestone in the same neighbourhood, identical, but for the changes which such formations undergo when similarly situated, with some of the white limestone series above, further shows that there is granite here, which may be of still later date even than that enveloping the gneiss. The gneiss itself *in situ* I did not see, unless this be a part of the sandstone thus changed into gneiss.

We have also witnessed the dioritic and euphotide rocks, which prevail on the north-eastern third of the coast, enveloping jaspideous strata at Masira and Ras Jibsh; at the same time we have seen nummulitic strata resting on them at Măskat and Masira, Marbat, and probably at Makalla, but in no instance have we observed either the granite or the dioritic rocks overlying this series; while on the south-western third of the coast we have seen a chain of volcanic vents up to Aden, inclusively, extending through everything, and an issue of black basalt and other volcanic rocks from them, which have overflowed the maritime plain in different places to a great extent. What the nature of the igneous rock may be at Ras Shuamiyah I know not, having only seen it from the sea,

Lastly, we have observed that the original localities of eruption of igneous rocks on this coast appear to have been the principal ones of the subsequent eruptions and out-pourings with the exception of the volcanic rocks, which have come to the earth's surface, where the older igneous rocks do not appear.

Let us now go to the aqueous formations; and these we may separate into three *Groups*, viz. 1st, the strata of which the highest scarps are composed; 2nd, the nummulitic or compact, littoral deposit on the shores especially of Dofar; 3rd, the Miliolitic or loose littoral deposit; and 4th, the recent littoral deposit.

First Group.

This admits of three divisions. The first or uppermost includes the white limestone series, which extends from the summit of the table-land to the commencement of the coloured argillaceous strata. It consists of white calcareous strata of different degrees of fineness and hardness, some being coarse compact, others compact and lithographic, and some chalky and argillaceous, but the compact lithographic form apparently predominates. They are more shelly above, perhaps, than below, and throughout more or less charged with small thin Foraminifera. In some parts flints are imbedded in them, chiefly in the more compact lithographic form, as may be seen from the fragments in the talus of the great scarp at Marbat,

Resut, &c. Towards the summit *Cyclolina* which is confined to the Cretaceous Series (D'Orbigny), and *Alveolina* abound, with bivalves and univalves, closely allied in form to those of the Nummulitic Series, while towards the lower part *Orbitolina* abounds with fossils, which are undoubtedly of the cretaceous period.

I regret that I cannot state more of the middle part of these strata, but here and there, where they were accessible, we did not land, and where we did land they were for the most part too suddenly scarped to be attainable. At Fartak, as already stated, the lowermost are more or less magnesian, and in some parts dolomitic; but this, which we have frequently observed in this series on other parts of the coast, seems to be owing to local causes.

We now arrive at the second division of the group, which comprises the coloured Argillaceous Series, and this we have estimated at 300 feet at Marbat, 175 feet at Ras Sejăr, and 1,000—1,200 feet at Ras Fartak.* We have also observed it to consist of red, blue, green, and yellow argillaceous strata, sandy shales, and impure limestone, in which a red colour is most predominant; and to contain, in addition to *Orbitolina*, throughout, but most numerous in the lower part, species of Echinodermata, *Isocardium*, *Pecten*, *Plagiostoma*, *Exogyra*, *Ostrea*, and *Ammonites*, probably all of the Cretaceous Period.

The third and last division of this group is the Micaceous Sandstone, of which we have seen so little that all that can be stated is that it is of great thickness, and, though laminated in some places, is, for the most part, massive throughout. As before observed, it fines upwards as it passes into the argillaceous division, and becomes coarser towards the bottom, where the gritty particles of which it is chiefly composed are evident to the naked eye. At Marbat it is mostly of a ferruginous yellow ochreous colour, and at Ras Sejăr its upper part, which is the only portion of it exposed, is of a light greenish blue colour, veined here and there with white quartz.

Second Group.

We now come to the second group, or Nummulitic Series, which we have seen best at Măskat, on the island of Masira, all the way between Marbat and Ras Resut and at Makalla. At Măskat and Masira resting on dioritic rocks and euphotide; at Marbat and Masira on the same kind of rocks with granite, presenting at all these places gypsum; and between Marbat and Resut on compact white limestone, without gypsum.

At Măskat and Masira, consisting above of yellowish, compact limestone, pregnant with small Foraminifera; below this, shells abounding;

* Almost all the heights and thicknesses given, with the exception of those stated to have been computed by trigonometrical measurement, have been assumed, or obtained in a rough way, for, as these observations formed no part of the survey, the means of making them accurately were of course very limited.

and below this, corals; then arenaceous limestone, pure sand, and conglomerate. Bearing nummulites in some part of the gritty calcareous division at each of these localities.

At another part of Masira, on the island of Hammar el Nafur, and at Ras Kariat, resting on clays, ferruginous at the former, of a greenish-white colour at the latter two places.

Between Marbat and Ras Resut, consisting of compact shelly limestone (bearing a bed of *Orbitolites* and *Orbitoides* at Takah, midway between these two places), with coralline limestone below, followed by limestone conglomerate more or less charged with small pebbles from the igneous rocks, resting on compact white limestone.

It is true that no nummulites were observed here, but a less hurried examination than that which circumstances compelled me to make of this and many other localities on the coast would no doubt have been attended with more satisfactory results. At Takah, however, the presence of *Orbitolites* and *Orbitoides* with the serial characters of the strata between Marbat and Resut, are quite sufficient for us to identify this with the other Nummulitic Formations above described.

Throughout I have never been able to detect *Alveolina* in these deposits.

Third Group.

Lastly comes the third group, or Miliolitic Deposit, which is chiefly characterized by its loose structure. In its purest state, as at Ras Abu Ashrin, that is, where it is not mixed with the coarse littoral *débris* of shells, or aqueous or igneous rocks, we have seen it to be composed of minute grains of calcareous matter, with which is mixed a small quantity of hyaline quartz; the former being nothing more than the tests of microscopic Foraminifera, loosely cemented together by a partial dissolution and re-crystallization of the external parts of their shells. The purity and whiteness of this deposit is, of course, in proportion to the distance it has been formed from the shore, or the neighbourhood of coarse, loose material; hence, in addition to the locality mentioned, it is very pure in the plain of Dofar, on the western side of Ras Sejăr, and in the sandy plains on each side the port of Kishn, while, in most other parts, we have seen it mixed with large shells, pieces of coral, and rocks of the neighbourhood. Perhaps 100 feet is about its average thickness. It exists at various degrees of elevation, from 15 to 150 feet high, throughout the coast, and at one place, viz. on Jibal Ghara at Makalla, it is raised to the height of 1,300 feet. At Resut it is found filling the lithodomous excavations in the coarse shelly limestone of the "*Second Group*," and there also it contains oysters of the same species as those of a recent bed close by. At Marbat, where it fills the fissures of the granite plain, it contains a number of shells and corals, many of which are very large, Hippopus, Ostrea, &c.—one species of the latter is

perhaps the largest known, it exceeds in size *Ostrea latissima* (Desh.). We have also seen that it is not only met with throughout this coast, but that it extends to the peninsula of Kattywar, in India, from whence it is imported at Bombay for building stone; and, from forming the lower part of the Desert of Akhāf, opposite Masira, it may perhaps be continued into the heart of Arabia. Of the *Fourth Group*, or Recent Deposits, I need say nothing more than that parts of these, like the foregoing, afford evidence of the elevation of the coast being continued.

Tabular Arrangement.

From the foregoing data, then, and in the absence of more extended and precise information, we obtain the following table of the aqueous strata at Măskat and on the South-east Coast of Arabia :—

RECENT DEPOSITS.	
MIOCENE AND PLIOCENE PERIODS. *Miliolitic Deposit,* 100 feet ?	Loose granular deposit of white calcareous particles, chiefly consisting of the remains of microscopic Foraminifera; with which is mixed a variable quantity of coloured siliceous particles of igneous rocks, and, in some places, shells, corals, and rounded pebbles of the neighbouring formations, far exceeding in proportion the finer material; shells and corals more or less loosely imbedded in the latter, and retaining, for the most part, their original whiteness and structure.
NUMMULITIC SERIES. 100 to 200 feet?	Coarse, compact, yellowish or whitish limestone, pregnant above with small Foraminifera, then abounding in shells, and below this charged with corals; passing into argillaceous deposits entirely, or into sands, becoming conglomerates. Bearing Nummulites, Orbitoides, Orbitolites and fossils of the Nummulitic Series. Resting conformably on diorite and euphotide, or on limestone.
UPPER CRETACEOUS PERIOD. 2,000 feet ?	*Upper Division.*—Coarse, compact, shelly limestone, bearing *Cyclolina* and *Alveolina*, with Foraminifera and fossils resembling those of the Nummulitic Series. *Lower Division.*—Fine, compact limestone strata, more or less lithographic in structure, of different shades of grey and white, bearing *Cyclolina*, *Alveolina*, and fossils in their upper part, like those of the Nummulitic Series.
LOWER CRETACEOUS PERIOD. 1,000 feet ?	Argillaceous strata, composed of impure limestones, clays, and shales, of different colours, principally red, richly charged with *Orbitolina*, in beds towards the lower part, containing Echinodermata of the genera *Discoidea*, *Pygaster*, *Diadema*, and *Salenia*; Pecten, Plagiostoma (?), Ostrea, Exogyra, and Ammonites.
1,700 feet ?	Compact micaceous sandstone, growing coarser towards the bottom.

Encouraged by the testimony of the celebrated author of the "Histoire des Progrès de la Géologie* (the Vicomte d'Archiac) in favour of the existence of the Cretaceous Series on the South-east Coast of Arabia, I have reconsidered the facts contained in the first edition of this Memoir, and re-examined my specimens, which has enabled me to name, with much more precision than formerly, the different groups of strata as they have successively come under consideration in their respective localities. The difficulties under which I laboured when writing the first edition of these observations were the want of knowing the value and nature of several of my fossils, whence I was inclined to give the Nummulitic Series more importance in thickness and height of position than it can claim on this coast. I thought that it might cap the summit of the white limestone series in the great scarps about Marbat, &c., instead of seeing it, as I now do, lying in humble, horizontal line at their bases; and presenting a cliff not thicker, in proportion to the scarp above, than 1 to 34, or 100 to 3,400 feet, which is the height of this declivity opposite the village of Marbat;—for the presence of *Cyclolina* (which, according to D'Orbigny, is confined to the Cretaceous Period), in the summit of the former, and that of *Orbitoides* and *Orbitolites* in the latter, together with the correspondence of the latter, in point of stratification, to the Nummulitic Series in other parts of this coast, not only points out the separation of these two scarps by fossil remains, but that of the formations of which they are composed by distinct periods of elevation. That of the Cretaceous Series probably took place during the effusion of some of the Granite and Serpentine Rocks, as portions of limestone similar to that of the Cretaceous Series immediately above are enveloped in them at Marbat; and that of the Nummulitic Series during the effusion of Trappean Rocks, as seen at the island of Masira, where it rests conformably on Serpentine and Diorite with a subsequent effusion of Trappean Rocks all around.

This re-arrangement has compelled me to add what I had before considered Miocene to the Eocene Group, and to assign to the former and Pliocene eras the Miliolitic Deposits, a somewhat empirical adjustment, perhaps, but such as must suffice at present for more extended examination.

* Vol. v. p. 410.

SUMMARY OF THE GEOLOGY OF INDIA,

Between the Ganges, the Indus, and Cape Comorin.

By H. J. Carter, Esq., Assistant Surgeon, H. C. S. Bombay. With a Map and Diagram.*

[Presented August 1853.]

It is but a few years since that the late Captain Newbold, of the Madras Army, wrote his "Summary of the Geology of Southern India," which was published in vols. viii. xi. and xii. of the Journ. of the Royal As. Soc.; and certainly no one has ever preceded or followed him in India whose opinions are entitled to so much respect, from his general geographical and geological knowledge, his active powers of observation, and his great personal experience of the country about which he has written. It is to be regretted, however, that he did not include that part of India between the Ganges and the Indus; because, with his actual acquaintance with the former, and the published observations on the latter, he might have drawn much more faithful and useful comparisons between the two than one behoving almost entirely to the observations of others for a summary of both.

As it is, there is nothing left but a careful perusal of all that has been written, directly and indirectly, on the subject, for at least the last twenty years, with frequent reference to a museum of authenticated specimens, before the student can feel himself master of what has already been done, and enabled to proceed with confidence to further investigation.

Very few, however, possess such opportunities, although there are hundreds so situated in India, who, if they could be conveyed to them, would not only be able to examine their respective localities efficiently, but be most grateful for the means thus afforded of additional occupation.

Feeling sensible of this, at the same time that it is impossible to transfer such advantages in bulk, I have endeavoured to supply their place, by giving a short summary of all the principal facts and conclusions to which an attentive study of the observations of others and my

* Reprinted with "Foot-notes," from the Journal of the Bombay Branch of the Royal Asiatic Society, vol. v. p. 179.—January 1854.

own limited experience on the subject have enabled me to arrive, wishing that this long-desired compilation had been undertaken by a more competent person.

The part of India I propose for our consideration is comprised within the Ganges and Jumna on the NE., the Indus and Sutlej on the NW., the Bay of Bengal and Arabian Sea respectively on the E. and W., and Cape Comorin on the S.; cutting off, however, that angular portion which is NE. of a line extending from Delhi to Ferozepore, as this would entail a description of the geology of the Sub-Himalayan range, which, besides rendering the subject much more complicated, and being almost entirely without the natural boundaries of the tract mentioned, I am not prepared to enter upon.

With the general geographical features of this tract I must presume that the reader is already acquainted, and, therefore, shall only add a small map, to facilitate his finding out the places and localities to which I may have occasion to direct his attention.

Numerous as the geological observations on the portion of India before us appear to be, there are still so few, comparatively speaking, of general bearing, and these on localities so widely separated, that, after having perused many hundreds of pages, the student finds himself barely on the threshold of his subject, and, with but a faint sketch even of the most prominent geological features of the country he at first thought so well known. Such, however, must always be the case in an attempt to generalize from unconnected facts and data loosely described, which most of these are. Yet India has not been without her able, faithful, and devoted geologists; but the treachery of her climate, her uninhabited wastes, where her rocks are best seen, her extensive and impenetrable tracts of vegetation, and her stratified formations metamorphosed and unfossilized by the intense heat of repeated intrusions of igneous matter, have, all combined, opposed the development of her geological history, and the former sent many an efficient enthusiast to an early grave, ere his task of practical examination had hardly been commenced.

The progress of Indian geology is, therefore, necessarily slow, and its advancement now almost impossible, without a previous knowledge of what has already been done; which, however much more advantageously obtained by personal observation in a temperate climate, with an abundant and highly civilized population, will not admit of a similar exchange in India, where the uninhabited and unhealthiest parts are generally the most instructive, and can hardly be expected to be visited more than once by the same individual.

Limited, however, as our actual acquaintance with the geology of India may be, there is still enough to foreshadow a systematic outline

of what really exists, and which, if learnt, may materially facilitate the further development of her mineral and geological resources.

It will hereafter be seen, that in the tract mentioned we have, at least, representatives of all the geological series of Europe, from the Oolitic Period down to the present time, with metamorphic strata, and plutonic and volcanic rocks in abundance, such as are to be found in other parts of the world. So far, the Oolitic Deposits appear to be the most interesting, both in an economical and in a geological point of view; for they not only contain the coal-beds of India, iron-ore, and a very fair lithographic limestone; but in their metamorphic state, appear to afford the white marble of India, which, together with the red coloured sandstone, another part of the series, form the chief materials of the famous Taj Mahal at Agra, and the sandstone that of all the principal buildings of the towns on the Jumna from Mirzapore to Delhi. At Ajmeer and elsewhere the same sandstone, apparently metamorphosed, yields lead and copper; copper is found in the shales also of this series; serpentine in Bahar; steatite (potstone) in many places; magnesite near Jubbulpore, &c.; and the researches of Captain Franklin and Jacquemont in Bundelkhund, and Voysey in Southern India, would seem to show that the original conglomerate, if not the real bed of the diamond, almost invariably accompanies the Oolitic Series; while the late discoveries of the Rev. Messrs. Hislop and Hunter in the neighbourhood of Nagpore have shown that these deposits abound in by far the most interesting fossils that the interior of India has yet afforded.

The so-called cornelian mines, again, at Rattanpore, about forty-two miles inland from the mouth of the Nerbudda, would appear to be in an old beach, chiefly formed of rounded flints from amygdaloidal rocks; but these, and other conclusions of a like nature, had better be given in connection with the facts from which they have been derived, lest the mind of the reader be biassed in anticipating that which, after all, may prove to be fallacious; the object of this "Summary" being, not so much to insist on the correctness of the views it may contain, as, in the absence of more extended data, to place something before the reader which may draw his attention to the subject.

With this short introduction, let us proceed at once to the description of the different formations, commencing with the oldest, and ending with the most recent. These will be separated into Groups, headed respectively with a tabular view of their contents.

For authority, the author's name alone will be given, the titles of his publications being inserted at the end of the article; and, when reference is made to a specimen in the Society's Museum, the letters Mm. will precede the contributor's name, likewise P.MS. for private manuscript.

In the spelling of the names of places I am compelled to follow that of the Maps as much as possible.

GROUPS.

I.

Primitive Plutonic Rocks.

This group is intended for the primitive granitic rocks of India, when such shall have been determined. So far, the observations which have been communicated on the plutonic rocks are, comparatively, so scanty and so unconnected, and in every instance these rocks themselves so intimately mixed up with metamorphic strata, that primitive granite has not been satisfactorily demonstrated, and until this is done we must commence with the oldest *stratified* formations.

II.

Older Metamorphic Strata.

Gneiss.	*Quartz-rock.*
Mica-schiste.	*Micaceous-slate.*
Chlorite-schiste.	*Talcose-slate.*
Hornblende-schiste.	*Clay-slate.*

Granular Limestone.

I have called these "Older," in contradistinction to newer metamorphic strata, which also exist in India. They may be generally known by their composition, and by their being frequently veined with rocks of the secondary granitic series.

Gneiss.—This rock appears to be by far the most general and abundant of all the metamorphic strata. It occurs at Oodeypore (Dangerfield), near Baroda (Mm. Fulljames), Zillah Bahar (Sherwill), Rajmahal hills (M'Clelland), Phoonda Ghàt (Mm. DelHoste), Northern Circars (Benza), more or less throughout the peninsula to the Palghaut (Newbold), and probably to the extremity of India. It forms, with the other hypogene schistes, the scarp at the falls of Gairsuppa, which is 888 feet, to the water below, and the latter is 300 feet deep (*id.*). Christie considered this to be primitive gneiss: it is veined by granite (Newbold), which Christie also considered not the oldest. It is also veined by granite at Wallavapore, in the bed of the Toombudra, thirty-five miles WSW. of Bijanuggur (Newbold), Chittoor, on the Eastern Ghàts, top of the Bisly pass above Mangalore, the Palghaut, Sunkerrydroog, and Bangalore (*id.*).

It contains specular iron ore (Siderocriste) in most places: western extremity of the Vindhya range (Fulljames), Rajmahal (M'Clelland), in large beds at Malwan, on the Malabar Coast (Malcolmson), and at

Hazarecbagh is a bed of flinty brown iron ore of a pitchy lustre, and splintery fracture, 20 feet in thickness (Williams *apud* M'Clelland). Graphite replaces the mica at Banuswar near Bangalore (Newbold), Tinnevelly, and Travancore (Major General Cullen). Tin is found in it, on the banks of the Barakur, within a few miles of the town of Palamow (M'Clelland). Beds of garnets are common in it everywhere, corundum in Southern India (Christie), and beryl in the Mysore (Newbold).

It varies in composition, texture, and colour, containing more or less mica, being more or less compact, massive or schistose, and varying in colour from speckled, black, brown, reddish, to grey and white. It is also tinted green sometimes, when chlorite replaces the mica. When very fine-grained and decomposing, it bears a close resemblance to fine-grained sandstone.

Mica-schiste.—This rock, though not so often mentioned as hornblende schiste or gneiss, is probably always more or less present in parts of the latter. Like it, also, it contains garnets in the Southern Mahratta Country (Malcolmson), western extremity of Vindhya range (Mm. Fulljames), &c. It seems to pass into micaceous slate at the Phoonda Ghàt. Newbold states that, although generally veined with quartz, he never saw a vein of granite passing into it.* Being associated with gneiss and hornblende-schistes, they of course pass into each other.

Chlorite-schiste.—This, like mica schiste, contains garnets in the Southern Mahratta Country, and passes into mica schiste and gneiss, to which it is subordinate; also into steaschiste (potstone), massive and laminar, and into chlorite slate and clay slate. *Talc-schiste* is almost synonymous with *Chlorite-schiste* in geology, though talc and chlorite differ in mineralogical composition. Talc is frequently much more difficult to distinguish from chlorite than the latter from mica, by any empirical character.

Hornblende-schiste.—This rock, though not so abundant as gneiss, is just as frequently mentioned. It forms the eastern and western sides of the Neilgherries, where it is from five to seven miles in breadth, and slopes pent-like on either side on the granitic rocks which form the central axis of these mountains (Benza). Like gneiss, garnets are common in it at the Neilgherries (*id.*), Southern Mahratta Country (Mm. Aytoun), and corundum in Southern India (Newbold), &c. It contains magnesite, and chromate of iron in veins, at Karpur, four miles north-west of Salem, and green garnets in quartz veins at Sunkerrydroog, about twenty miles SW. of Salem (*id.*). Actinolitic forms of this schiste are frequently mentioned by Newbold. It is also found, with mica

* The latter must have been an oversight, I think, for it must occur often, and the Rev. Mr. Hislop has mentioned to me an instance of a granitic vein passing through mica-schiste in the neighbourhood of Nagpoor.

schiste on the Malabar Coast, which often passes into it (Malcolmson, and Mm. Aytoun).

Quartz-rock.—Commencing in the north, Jacquemont states, in his journey from Delhi to Bombay, that all the hills are composed of quartz from Delhi to Alwar, as well as between Ajmeer and Oodeypore. The quartz of the mountains at Ajmeer is compact and granular, with disseminated mica, and of a violet, grey, brown, or red colour. Tod mentions the summits of the diverging ridges from Ajmeer as being "quite dazzling," from their "enormous masses of vitreous rose-coloured quartz." On the great tract of slates forming the Suloombur range, about half a mile north of Maunpore, a little village situated on its ordinary summit, are two hills from 150 to 200 feet high, composed entirely of compact white semi-transparent quartz, in parts tinged with red, which, from its brilliant white colour, contrasted with the sombre hue of the slates, makes these hills at a distance resemble "snowy peaks" (Dangerfield).

Immense beds of quartz abound, not only in the neighbouring hills, but in all the plains of Suloombur, and towards Oodeypore. From the summit of the mountains round the Deybur lake or Beerpore, rises "an almost perpendicular wall of a large conglomerate or compound rock, consisting of immense reniform, or compressed globular masses of hornstone or quartz, imbedded in paste of the same, but having interposed a large quantity of golden mica in brilliant small plates; thin beds of mica slate occur near the centre of the mountain, with small seams of felspar, and large imbedded masses of Lucullite" (Dangerfield). The brilliant whiteness of the quartz in the Southern Mahratta Country is also spoken of as being very striking, and Christie mentions ranges of hills there which are crested with limpid quartz, from the granite in which it is imbedded decaying on either side. Returning to the north, again, Jacquemont states that he saw a mountain at Alwar composed of nearly vertical strata of quartz, alternating with thin beds of black amphibolic, or argillaceous, or ferruginous limestone. Around Jaipore and Ajmeer loose micaceous sand prevails, with projecting rocks of white quartz, amphibole, mica schiste, and dikes of sienite; and four miles from Chittore a ridge of nearly vertical strata of quartz, resting against granite on one side, and alternating on the other in argillaceous schiste, on which again rests compact limestone. (See Jacquemont's section.) Quartz rock is found at the western extremity of the Vindhya range, associated with mica slate (Hardie and Mm. Fulljames); and at its eastern extremity "in subordinate beds" in "old blue slate," but "mostly occupying a position between the older and newer varieties of slates, stratified," and "reposing on the back of old blue slate mountains in tabular masses, thus forming mountain declivities uncovered

by other rocks. A columnar fibro-slaty variety is found between the newer and older clay slate in nearly erect strata, passing on the one side into blue, resinous, conchoidal quartz, and on the other into the newer clay-slate" (M'Clelland). Other hills of slaty quartz and of hornstone in the same vicinity, may be referred to the same formation (*id.*).

Veins and large beds of quartz, more or less amethystine, are present in the granite plains of Hyderabad (Voysey). They occur also more or less throughout the peninsula; but the existence of quartz rock is not so often mentioned in the southern as in the northern part of India; indeed, after crossing the Toombudra, this rock on the western side of the peninsula appears to be subordinate in development all the way to the extremity of India, and micaceous and clay-slate never, to my knowledge, mentioned.

It contains lead and copper at Ajmeer (Jacquemont and Dixon), where both are in a granular form, and iron and copper in the Southern Mahratta Country (Mm. Aytoun). Mica is frequently found in large masses, and disseminated throughout the rock; talc, also, and chlorite, occasionally; and there is an extremely beautifully green specimen from the Southern Mahratta Country, coloured apparently with the latter (Mm. Aytoun).

Micaceous slate and Chloritic slate.—These are but more or less laminar aggregates of fine clay and mica, or fine clay and chlorite, the former rendering the mass more or less sparkling in appearance, the latter more or less satiny and greasy to the touch. They both occur at the Phoonda Ghàt (Mm. DelHoste), and the latter in the Southern Mahratta Country. Micaceous slate also occurs in the Suloombur range (Dangerfield). Both pass into clay-slate, when the brilliancy of the one and the greasiness of the other completely disappear. Copper occurs in a talcose form, in the Southern Mahratta Country (Mm. Aytoun), but I am unable to state if it belongs to the old or to the new metamorphic rocks: my opinion inclines to the latter.

Clay-slate.—This formation appears to be of great thickness. It is both massive and laminar, and of a variety of colours. Tod states that "the Aravulli range is chiefly characterized by granite reposing on massive, compact, dark blue slate." In passing from the north-western part of Malwa to Oodeypore, across the Duryawud valley, and the Suloombur range, towards the Deybur lake, clay and chlorite slates are almost the only rocks met with for five or six miles. The Suloombur range is found to be almost entirely composed of clay and chlorite slates, in vertical or highly inclined layers, with subordinate beds of greenstone, greenstone slate, and a fine crystalline limestone (Dangerfield); and the great mountain chain which runs nearly in a direction north and south,

past the westward of Oodeypore, dividing Guzerat from Malwa, Rath, and Bagur, is, as far as it is known, principally composed of slates and primitive limestone (*id.*). In the Curruckpore hills, where micaceous slate passes into clay-slate, the latter occupies a belt of country twenty miles in breadth, extending across the direction of the strata (M'Clelland). The Nerbudda passes through mica, talcose, chlorite schiste and gneiss, superposed with dolomite between Lamaita and Beragarh, close to Jubbulpore (Franklin) ; and again, on the south side of the Nerbudda, between Mandela and Amerkuntak, Dr. Spilsbury states that "the schistes are like the scales on a Manis' back." Micaceous slate passing into clay-slate occurs in the Phoonda Ghàt (Mm. DelHoste), also in the Saltoor pass, in the Southern Mahratta Country (Aytoun). Voysey, in his last journey from the vicinity of Nagpore to Calcutta, *viâ* Sumbulpore, mentions "clay stone [clay-slate ?] in gneiss, in the bed of a watercourse between Kishenpore and Surekeela, just after having passed gneiss, hornblende schiste, and quartz rock, repeatedly alternating," and in alluding to its metaliferous character he adds : "At Calastry it contains lead-ore mixed with silver; at Nellore copper; at Nagpore manganese and lead-ore, and copper ; micaceous iron-ore is a very common product of this rock." Old clay-slate with flinty slate and limestone was seen by Dr. H. [Dr. Heyne ?] about the Kistnah (extracts from Dr. H.'s MS. *ap.* Voysey).

Micaceous and magnetic iron-ore occurs in clay-slate in the Southern Mahratta Country (Mrn. Aytoun), manganese in the Kupputgode range, in the same neighbourhood (Aytoun and Newbold), lead in the eastern Ghàts at Jungamanipenta (Newbold), plumbago in the branch of the Pulicat hills running south from Cuddapah (Dr. H. *ap.* Voysey). Tod mentions garnets in a hill of blue slate one mile east of Poorna, a little north of Oodeypore ; also on the frontier of Kishengurh and Ajmeer ; and mines of tin (?) and copper at Dureeba, close by. Aytoun's ENE. and WSW. section of the Kupputgode hills shows a vast quantity of iron schiste interstratified with chlorite "and micaceous schistes ; with talcose quartz, hornblende gneiss, mica slate, and hornblende schiste" on the ENE. side : one stratum of iron ore is 60 feet in thickness. Gold is found in the iron sand of the watercourses running from these mountains, and also from the Saltoor range adjoining, while in the centre of the Kupputgode range are two hills called the "great" and "little" gold mountains.

Granular Limestone.—Connected with the old metamorphic strata, appears to be a limestone, though the fact is by no means substantiated, on account of the metamorphosed state of much of the Oolitic limestone of India. Captain Dangerfield mentions subordinate beds of a "finely

granular crystalline limestone, of a light grey colour, occurring with greenstone slates in the clay and chlorite-slates of the Suloombur range, at Maunpore, between Malwa and Oodeypore"; also "imbedded masses of Lucullite of a black colour, and dull conchoidal fracture," with thin beds of mica slate and small seams of felspar, in mountains of gneiss round the Deybur lake, of the same neighbourhood. Jacquemont saw a mountain of quartz at Alwar, interstratified with thin beds of amphibolic, argillaceous, or ferruginous limestone, in vertical strata. There is a compact finely granular limestone, of a dark bluish-grey colour, associated with mica slate, in the Phoonda Ghàt (Mm. DelHoste). It has all the appearance of mountain limestone; while a still more compact variety of a lighter colour exists on several parts of the Malabar Coast in the neighbourhood: near the entrance of the Goa river, in very subordinate beds, associated with the chert and slate of that locality (Mm. Dalzell), this would be worth examining more minutely, as it evidently contains the remains of shells.* Limestone is found in hornstone slate in the Nulla Mulla mountains; and the lead mines of Jungamanipenta, in the eastern Ghàts, are in limestone associated with argillaceous and arenaceous slates and shales, "resting conformbly on the hypogene schistes," whose age Newbold states is undecided. He also mentions a layer of fine crystalline limestone, apparently magnesian, in gneiss broken up by granite, at Sunkerrydroog, with innumerable garnets in the limestone where it is in contact with the granite. Fine white, coarse-grained, highly crystalline limestone, with disseminated graphite, or with masses of green and clove-brown hornblende in laminar or granular crystallisation, occurs, in the district of Tinnevelly (Mm. Major General Cullen); and a similar kind without these minerals, but with and without a dissemination of talc, exists in the neighbourhood of Nagpore (Mm. Rev. S. Hislop).

Obs. As with the *Quartz-rock*, so with the *Clay-slate* and *Granular Limestone*, there is in many instances no possibility of determining which belongs to the older, and which to the newer Metamorphic Rocks, from present observations; and they never will be satisfactorily described and distinguished throughout India, until they are examined by a practical geologist, on the spot, well acquainted with Indian geology. There are evidently two metamorphic series, at least; and until their respective minerals and characters are determined, they will be perpetually confounded. I think it extremely probable that I have unavoidably done this, but I must be content to leave future investiga-

* It is a fossiliferous and not "granular limestone," and therefore is not entitled, in this state, to a position here, whatever may be its phase in other localities, but at present we know nothing more about it than that above mentioned, and it is placed here for convenience and to attract attention.

tion to point out my mistakes; let us now direct our attention to the rocks by which these strata were first penetrated.

III.

Secondary Plutonic Rocks.

Granitic or Felspathic.	*Granite.* *Protogine.* *Sienite.* *Pegmatite.* *Leptynite.* *Eurite.*	Diallagic	*Euphotide.* *Eclogite.*
		Amphibolic or Hornblendic.	*Amphibolite.* *Hemithrene.* *Diorite.*

Granitic or Felspathic Rocks.

Granite.—Huge masses of a compressed round or cuboidal figure, heaped upon each other irregularly or in columnar piles and erratic blocks, compact, or undergoing concentric laminar decomposition *in situ*, or in detached portions, form the grand characteristic features of this formation in India as well as elsewhere; and as it appears to exist more continuously, and to a greater extent, in the neighbourhood of Hyderabad than in any other district, so its features are, perhaps, more strikingly developed in this than in any other part of India. Voysey states, that on quitting the banks of the Kistnah, granite alone, chiefly of a red colour, is the basis of the country to the Godavery. Red felspar seems to be the predominant ingredient in the secondary plutonic rocks throughout India. The granite, which veins the metamorphic strata, appears to be principally red, though not always, for at the falls of Gairsnppa it is grey, and sometimes it is red in one part of the vein and grey in another (Voysey); while at Goontacul, near Gooty, a still younger red granite is seen to vein the older secondary one (Newbold). Captain Jenkins mentions a grey granite at Ramteek, in the hills NE. of Nagpore, composed chiefly of whitish felspar in very large crystals, which is traversed "three or four times" by granitic veins, the granite becoming finer in structure, and redder, as it is more recent. Red granite, however, is far from being exclusively the colour of the secondary granites, though it seems to be the most prevailing one.

Protogine, Sienite, Pegmatite.—The granitic rocks vary in structure and in mineral composition as they do in colour—hence these appellations; at one place they are sienitic, at another protoginic, and at a third pegmatitic, while a very common form is the quaternary compound called *Sienitic Granite*, from its containing hornblende as well as mica. This is the prevailing felspathic rock of the Neilgherries (Benza). Christie was of opinion that white and red sienites were the most prevalent rocks of the peninsula; and that, from being associated with

granite, they were the same as those of Egypt. All who have observed the felspathic rocks of India, have been struck with the large size and beautiful flesh-colour of the crystals of felspar, and of its frequent prevalence in place of the other ingredients. At Severndroog some of the reddish-coloured crystals are nearly two inches long, and imbedded in a small-grained reddish granite. Some of the dark-red crystals at Roan in the district of Dharwar, contain minute veins of quartz, and cavities filled with crystals of chlorite (Christie); and occasionally in the Southern Mahratta Country the whole mass consists of red crystalline felspar, granular or in large crystals (Malcolmson, and Mm. Aytoun). Mica appears to be very sparingly disseminated in the large-grained red felspathic rock, and is frequently replaced by green chlorite, rendering the rock protoginic. Sometimes it is replaced by actinolite (Newbold), and occasionally by epidote. The latter, with red felspar, forms a beautiful rock, in the western extremity of the Vindhya range (Mm. Fulljames); but I am ignorant of its extent. In the Southern Mahratta Country the red felspar is sometimes accompanied by quartz only, which, being transparent and colourless, forms when coarse-grained, a beautiful pegmatite (Mm. Aytoun). A grey granite prevails at Vencatagherry, which, at Naikenery, at the top of the Moglee pass, contains nests of mica as large as a man's head (Newbold). Sometimes all kinds of granite and granitic rocks may be found in different parts of the same mountain, as in that at Bellary (*id.*). At Bijanuggur the granite is generally red; at Vingorla, on the Malabar Coast, it is grey.

Tracing these rocks through the tract mentioned, and beginning in the north, we find none in Cutch (Grant); but at Nuggur in Parkur there is a hill of red and white sienite (*id.*), which can be traced on in masses just projecting above the sand to Balmeer, and its immediate neighbourhood, where the granitic mountains are 1,200 to 1,500 feet high, and the felspar of an opaque reddish yellow, or flesh-colour, imbedded in a fine-grained sienite (Mm. Forbes). At Jessai, which is a village among this group, the granitic mountains have been deeply fissured by subterranean violence (*id.*). At Mount Aboo there is granite again (Mm. Waddington); and the Aravulli range consists chiefly of it "reposing on slate," as has before been mentioned (Tod). At Ajmeer and around Jaipore red granite and sienite are seen in veins and dikes traversing the hills and mountains of quartz, which project above the sand in these parts (Jacquemont). Between Oodeypore and Malwa are all the varieties of granite above mentioned, the red and largely crystallized always predominant (Dangerfield). They extend more or less southward to Chota Oodeypore, near the Nerbudda (Hardy and Dangerfield), and form part of the western extremity of the Vindhya range near Baroda (Mm. Fulljames). The Girnar mountains in

Kattywar consist of a grey sienitic granite (Mm. Aston), and granite mounds are seen projecting above the surface on the site of the ancient Valabipura, a few miles N W. of Gogah, in the same peninsula (Nicholson). Passing to the neighbourhood of the eastern extremity of the Vindhya range, we find the fort of Kallingur, about 110 miles W. of Mirzapore, situated on a hill formed of red sienite capped with sandstone (Jacquemont), and several sienitic mounds in the vicinity. Enormously coarse-grained granite is met with in the Zillah Bahar, as well as fine-grained passing into eurite (Jacquemont and Sherwill); and red sienite near Currnckpore; also in the Bhagulpore and Monghyr districts, on both sides the Ganges, and veining gneiss with trap two miles from Luchmipore (M'Clelland). Returning to about midway between this and the mouth of the Nerbudda, we have granite on the south side of the latter, between Mandela and Amerkuntak (Spilsbury); also sienitic granite with flesh-coloured felspar at Jubbulpore, thirty miles in extent (Franklin); at Baitool, close to the northern border of the great trap district (Finnis); veining limestone, and bursting through the sandstone overlying it at Nagpore (Malcolmson); in Cuttack (Stirling), Orissa, and the Northern Circars, which, with the province of Bahar, are almost unexplored districts, as far as their geology and mineral resources are concerned. Its great extent in the district of Hyderabad has been mentioned. At Vingorla, on the Malabar Coast, it limits the great trappean effusions of Western India; and thence southward, with the other felspathic rocks, forms the grand plutonic net-work of the peninsula. There is a granitic ridge a mile long and 120 feet high at the seven Pagodas, between Madras and Pondicherry, close to the sea (Newbold); and at the Amboli pass, about twenty miles from Cape Comorin, the mountainous tract of Southern India ends in a bluff peak of granite, probably about 2,000 feet high, from the base of which a low range of similar rocks extends southward to the sea (Calder). Everywhere the red felspathic granitic rocks are mentioned more than the grey or white felspathic variety; everywhere, almost, the former appear to vein the metamorphic strata, where they exist; and almost everywhere both secondary granitic and metamorphic rocks appear to be again veined or diked by greenstone (diorite) and the trappean rocks.

Leptynite, Eurite, and Porphyry.—The first is occasionally mentioned by Newbold, and *Eurite* not unfrequently; but *Porphyry* very seldom. With the exception of a dike passing through gneiss at the northern sally-port of the fort of Seringapatam, near to which Tippoo was killed, I know of no other to which prominence is given. This, which has been described by both Benza and Newbold, is said by the former to consist of "well-defined crystals of red felspar, which is occasionally

white, imbedded in a paste of compact felspar of the same colour." It also contains "tourmaline in numerous needle-shaped crystals."

Diallagic Rocks.

Abundant as these rocks are on the South-east Coast of Arabia, where, with serpentine and diorite, they in extent almost represent the trap of India, there is only one place in India where euphotide is clearly mentioned, and that is at Banuswar, in the Mysore, a little west of Bangalore. Newbold, who has described it, states that it differs from the euphotide of other parts, in being a compound of felspar and quartz, with the latter predominating, the diallage varying in colour from olive-grey to smaragdite-green.*

Hornblendic Rocks.

Diorite or Greenstone.—This rock differs from the fine-grained diorites of the trappean effusions, to which we shall come by-and-bye, in being of a coarser structure, entirely crystalline, and not containing the small portion of amorphous or uncrystalline earth accompanying the latter; in presenting no vesicular cavities, and no zeolitic minerals, but imbedding, if anything, chiefly talc, mica, or garnets. Besides these differences, it seldom overlies the other rocks to any extent, occurring chiefly in veins, intercallations, dikes, or mural ridges, the latter, sometimes, with granite on each side (Malcolmson).

Its structure, composition, and colour vary: for the most part, perhaps, it is largely granular, crystalline, and of a dark or black green colour, when it is almost wholly composed of hornblende, and therefore closely approaches Brongniart's amphibolite; or of a granitoidal aspect and structure, when it consists of equal quantities of felspar and hornblende; or porphyritic, when it is fine-grained, with one or the other of its ingredients in large crystals.

An "old trap" is said to exist in the "big" and "little Mounts" at Madras, and on the granite of the seven Pagodas, which is compounded of "felspar, hornblende, and quartz, with a small proportion of mica, pyrope and epidote, which enter it as foreign minerals" (Dr. H. *ap.*

* I think, however, that I can perceive among the specimens from the trappean district of Western India in the Asiatic Society's Museum, some which are closely allied to diorite and the serpentine (euphotide) of Arabia; and this might be expected, not only from the proximity of the two countries, with serpentine and diorite prevailing in the latter diked with trap, but on account of the outburst of igneous rocks taking place for the most part at the localities of original eruptions. Hence it is not improbable that serpentine and diorite may be enveloped in the great trappean effusions of Western India; a point of much interest in geological chronology, if it could be established, inasmuch as the Eocene Group of Southern Arabia, in many places, was deposited conformably on diorite and serpentine afterwards raised by trappean effusions.

Voysey). Newbold also describes a similar rock at Chinglepnt, thirty-six miles SSW. of Madras, which is garnetiferous. Amphibolites also exist in the Southern Mahratta Country, which are respectively micaceous and garnetiferous (Mm. Aytoun); and a beautiful diorite, compounded of equal parts of translucent, colourless felspar and dark green, granular hornblende, with chlorite disseminated in the latter. A compact greenstone, foliated, and ringing when struck, is often used for lingums (Dr. H. *ap.* Voysey). Common hornblende of an olive-green is found in the Bura-maul, in Noorcull, in primitive trap, with garnets (*id.*). A porphyritic greenstone is found in conjunction with sienite in a considerable tract between the villages of Curhurbalee and Palamow, in the zillah of Huzareebagh. The porphyritic structure is produced by small pieces of talc, of uniform size, disseminated throughout the mass of hornblende (M'Clelland).

Going to the southern part of the peninsula, Benza describes a tract of fifteen miles in extent, five miles NW. of Salem, which is composed of diorite veined with magnesite. The structure and composition of the rock is only seen from the surface, as there are no hills, only mounds, which are all interlaced with a net-work of magnesite veins from 0 — 3 inches in thickness, massive, or in cauliflower crystallization. Stromeyer found this magnesite to be composed of magnesia 47·89, carbonic acid 51·83, and lime 0·28. It is nearly anhydrous, heavy, and so hard in compact as to strike fire with a hammer, breaks with a conchoidal fracture, and has a waxy structure; also effervesces slightly with acids. Asbestus, talc slate, and nephrite occur here and there, and where the magnesite is in contact with the main rock the latter is ophitic. Another part of this diorite probably is alluded to by Newbold, who states that at Karpur, four miles NW. of Salem, is a hornblende schiste, alternating with talcose massive schiste, netted with magnesite veins, along which, also, chromate of iron runs, and layers of magnesian rock like serpentine, the whole of which is diked with basalt. Chromate of iron is also stated to exist near Trichinopoly, also with magnesite at Hansoor in Mysore (Gilchrist); and the latter in the Nellore district. Serpentine is often mentioned in subordinate beds in mountains or hills, among the hornblende schistes, but never serpentine or euphotide rock, occurring with diorite, as in Arabia. It is, perhaps, worth remembering, that the only part of India where hornblendic rocks, approaching to those of the South-east Coast of Arabia, have been noticed, is in the neighbourhood of calcareous beds belonging to the lower Cretaceous and upper Oolitic Systems; and these, again, have only been noticed in the southern part of the peninsula, between Pondicherry and Trichinopoly. May we infer from this, that the occurrence of these rocks in such prevalence on the coast of Arabia has been influenced by the

presence of the great calcareous beds there, and, therefore, that neither one nor the other ever have existed in the greater part of India?

Like the granitic, the greenstone rocks vein and dike the metamorphic strata almost everywhere, and, coming after the former, vein them also, while they are in their turn cut through by the trappean rocks.

As before stated, their greatest continuity is seen in mural ridges, and not as overlying rocks. They occur extensively both in the granitic district of Hyderabad, and throughout the peninsula (Malcolmson and Newbold). Some dikes have been traced for twenty miles continuously (Newbold). About Hyderabad they are from 100 to 300 feet broad, and may be traced from fifteen to twenty miles, occasionally spreading out a little (Voysey). About four miles south of Dhonee, between Gooty and Kurnool, there is a basaltic greenstone dike, 150 feet high and 200 feet broad, running through a range of sandstone and limestone mountains (Newbold), and near the village of Bunkapilly, within four miles of the Munjira, as well as on the banks of the Munjira itself, Voysey saw a "greenstone or sienitic greenstone" veined with granite, the granitic veins being in some parts red, in others white, and projecting two feet beyond the weathered surface of the greenstone. This must not be set down, however, as an instance of granite veining greenstone, for the genuineness of the latter is by no means apparent, from his calling it "greenstone or sienitic greenstone."

The other two rocks mentioned in the table, viz. *Eclogite* and *Hemithrene*, though probably existing, have not yet been mentioned in India. For their characters, as well as for those of the other rocks in this group, I must refer the reader to the article "Roches," by Alexandre Brongniart, in the Dictionnaire des Sciences Naturelles.

IV.

"Cambrian and Silurian Rocks" (M'Clelland).

Newer Clay-slate, with beds of Quartzose Breccia.	*Sienite.*
Transition or Cambrian Gneiss.	*Porphyritic Greenstone.*
	Hornblende-slate.
	Slaty Quartz.

We have now come to a period which followed the eruption of some, at least, of the red felspathic rocks, in which it seems desirable to bear in mind that the mica is frequently replaced by chlorite, rendering the composition protoginic, and that the crystals of felspar themselves sometimes contained chlorite. Voysey mentions the passage of granite about Hyderabad "from greenstone to potstone." Stirling mentions that the granite about Ganjam, in Cuttack, is chiefly red, and abounds in garnets, and

veins of steatite. Chlorite-slate, steatite, and hornblende, with mica, and abundance of garnets, all form parts of the metamorphic rocks, and we therefore must be prepared to meet their *débris*, together with those of the red felspathic ones which broke through them, in the sedimentary strata which immediately followed the eruption of the latter.

Such a system of stratified deposits appears to exist in the Curruckpore and Rajmahal hills, in the Bhagulpore district, where they have been studied by Dr. M'Clelland, who describes them provisionally, as they have as yet yielded no fossils, under the head of "Cambrian and Silurian Rocks," as follows:—

"*Newer Clay-slate and Quartzose Breccia.*"

"The old or primitive variety is succeeded by the newer green or Cambrian variety of slate: the greenish or newer clay slate, referred by authors to the transition or grey-wacke series, extends from Bhem Bhan to midway between Goordhee and Mungrah, being a distance of six to eight miles in a SW. direction, across the traverse of the strata, which run SE. and dip SW.

"The continuity of the old blue and newer green slates is interrupted by intermediate beds of quartz and talcose slates, which interpose between them.

"*Beds subordinate to the Newer Clay-slate.*—(*a*) Blue compact quartzose breccia veined, like marble, with white streaks, resembling transition limestone, occurs in beds of 5 to 50 yards in breadth, alternating with the newer clay slate, between Bhem Bhan and Goordhee.

"(*b*) Grey-wacke or Steatitic Sandstone.—This grey-wacke or steatitic sandstone forms the abrupt and precipitous ridge of outer ghàts at Guidore, where it is used as a building stone in the construction of the older fort at that place. It is a quartzose sandstone, containing steatite and diallage, which give the fresh rock a peculiar greenish yellow colour and resinous lustre, with a compact splintery fracture; all which characters it loses on long exposure, becoming an ordinary fine-grained, yellow, earthy sandstone.

"It terminates at the north side of the pass by which the Kewlee river enters the plains at Guidore, where it forms a bold precipitous escarpment, resting on mica slate.

"I have been long familiar with the characters of this rock in Kemaon, and although I never saw it covered by any other, yet I believe its proper place to be with those great quartzose beds which are connected with the newer clay slate, but never on any subsequent formation,—an important practical point to understand, as it places this rock considerably anterior to the sandstone of coal measures, for which it might otherwise be mistaken.

"*Transition or Cambrian Gneiss.*"

"This rock is of great extent in the Bhagulpore district, composing two-thirds of the intermediate country from the Curruckpore to the Rajmahal hills, together with the greater portion of the southern ridges of the Rajmahal group. It consists of quartz, more or less hornblende, lenticular nodules of felspar, more or less compressed and flattened, coarse garnet pebbles, and mica, all imbedded in a matrix of earthy, half-crystalline felspar. When the hornblende predominates, the rock assumes the form of a soft, pliable hornblende slate.

"These beds sometimes suddenly change into a fine granular structure, retaining all the ingredients of the coarser variety, but assuming the appearance of sandstone flags (between Mungra and Belharh).

"From the partial or complete decomposition of the hornblende and felspar, the rock often appears as a coarse pseudo-crystalline conglomerate, containing nodules of felspar. (Bed of the Bundooah river.)

"In other situations the formation assumes the form of slaty quartz, or a somewhat compact, but close granular structure, containing more or less mica and hornblende, chiefly the latter. Beds of this quartzose variety alternate sometimes with the coarse-grained rock. (Suyapatam.)

"In some situations the formation passes into and alternates with beds of micaceous and hornblendic schistose form, and even contains small beds of calcareous breccia; all which varieties are met with in the ascent from the ghât below Suyapatam, where the formation is much disturbed by outbursts of trap and quartz dikes.

"Thus the line of section from midway between Goordhee and Mungra to Suyapatam, a distance of twelve miles, at right angles to the direction of highly inclined strata, extends exclusively over this formation, the strata running during the first part of the section, with slight deviations, in the direction of NW., dip 45° to 60° SW.

"From Nungajoor to Luchmipore, the first part of the country along the same line of section is much disturbed and broken up by quartz dikes and rounded hills of trap. Amidst these disruptions, beds of the same coarse-grained slaty rock reappear at intervals, composing the country as before.

"After passing Luchmipore about a mile, in continuation of the same line of section, the rock is seen passing in places into sienite, with outbursts of which it alternates, more or less, all the way to Noonyhath.

"From this lastmentioned place to Kottycoon, a distance of twenty-four miles along the same line of section (still crossing the direction of the strata), the rock resumes its characteristic coarse crystalline slaty structure, much resembling gneiss, but distinguished from that rock by the addition of hornblende, which is always present in this, while it is of rare occurrence in primitive gneiss.

"It also differs from the primitive rock in the manner in which it occurs, filling up valleys, and forming low undulating plains between primitive mountains of clay slate and gneiss, as in the intermediate low country between the Curruckpore and the Bhagulpore hills; again (though broken up by eruptions of sienite), between Nangajoor and Noonyhath; and lastly, as it occurs in the somewhat elevated valleys composing the north-western declivities of the Rajmahal hills, extending from Noonyhath to Kottycoon, encircling the base, but never ascending higher on the acclivities of mountains.

"At Kottycoon it is succeeded by beds of granular slaty quartz and trap as before, and finally disappears beneath the conglomerate, underlying the coal measures.

"*Mineral Contents of Transition Gneiss.*—Garnets abound in this rock, more particularly in the vicinity of quartz dikes, where they form a large proportion of its substance, imbedded in earthy felspar and hornblende, from which they are dislodged by the decomposition of the matrix, and thus form a gravelly deposit on the surface of the soil (Suyapatam).

"The garnets here are of uniform size, and spheroidal shape, somewhat larger than a musket ball, and when sharply struck with a hammer, each nodule separates into two equal parts, without exhibiting a fractured surface. I observed the same phenomenon many years ago in quartzose vein-stones, from veins of clay slate in Kemaon. It contains no valuable minerals.

"*Sienite.*"

"This consists of unstratified, erupted masses, composed chiefly of crystalline felspar and hornblende, with a small proportion of quartz. Felspar is the predominant ingredient, and generally gives more or less of a reddish yellow colour to the mass. It forms lofty conical peaks, (Lugwah near Noonyhath), and rounded hills, each sometimes composed of a single unbroken mass (Panch Pahar in the Bhagulpore district, and Chara Pahar in Pergunah Currucdyah, between Palamow and Curhurbalee); or it is broken into smaller overlying masses, either protruding singly from the surface (near Luchmipore and Suyapatam), or accumulated in rugged pyramidal hills (Nanegore, near Bunta-Rampore, in Pergunah Mellypore, Monghyr district).

"These sienites sometimes pass into the transition gneiss (two miles from Luchmipore, on the way to Serieah, and also at the base of Lugwah hill, near Noony), and are also found in veins, along with trap, penetrating gneiss. (Bed of the Kuttooreah river, seven miles from Luchmipore.)

"*Mineral Contents of Sienite.*—This sienite contains galena at Panch Pahar (Sherwill), as well as at Turee Pahar, and some other places in the Bhagulpore district. In the firstmentioned locality the galena occurs in a decomposing bed of coarse granular quartz, glassy actinolite, or (as Mr. Dodd suggests), perhaps, coccolite and earthy felspar. The galena, in small crystals, constitutes about 2 per cent. of the mass."

At another part of the same district it is more abundant, and found by Mr. Dodd to be rich in silver.

"*Porphyritic Greenstone.*"

"This first appeared in the bed of the Kuttooreah river, seven or eight miles on the NW. side of Luchmipore, in the Bhagulpore district, where it occurs massive, as well as tabular and stratiform, consisting of hornblende and quartz. It is extremely hard and unyielding. The quartz in the massive variety is distributed into numerous diffused crystalline points, which are dispersed throughout the mass. In the tabular variety the quartz occurs in plates and flattened nodules, disposed in parallel lines with the tabular structure, presenting the appearance of hornblende slate, with which it corresponds in structure, at Soorudjajah.

"In this shape it forms a belt of country three or four miles in breadth, alternating in places with transition gneiss, both rocks being much dislocated by eruptions of secondary trap, which last occurs abundantly, particularly at Luchmipore.

"*Hornblende-slate.*"

"Beds presenting the appearance of hornblende slate, but containing quartz aggregated in compressed and flat lenticular-shaped nodules and plates, instead of felspar, occur in the Rajmahal hills in the bed of the Goornara river at Kottycoon, where it forms in some localities the basis of the coal measures, and in others it gives support to thick beds of granular slate quartz.

"The same hornblende slate also occurs in the bed of the Brahminy river at Buktahn Pahar, likewise forming the rock on which the coal measures rest. It extends from thence to Curracutta, where its line of junction with the conglomerates underlying coal measures is well shown.

"The hornblende slate marks the boundary of the coal measures for a distance of twenty miles, and forms considerable tracts of the adjacent country, where the coal measures disappear.

"This hornblende slate appears to be identical with the Luchmipore porphyritic greenstone; the only difference is that the quartz is aggregated in lenticular nodules, or compressed into plates, so as to produce a slaty structure, more, however, in appearance than reality, for the rock can scarcely be said to possess a slaty fracture, being very difficultly frangible; so that there is little or no real distinction between it and the Luchmipore rock, except the lenticular or laminated form of the quartz.

"*Slaty Quartz.*"

"This consists of granular quartz, for the most part of thick slaty structure, sometimes thick-bedded, but always more or less disposed to split into thin hard flags. It occurs capping indifferently the sub-crystalline and other trappean slaty rocks described in this section. The Dhunya mountain, at Kottycoon, in the Rajmahal hills, is composed entirely of these beds, affording a thickness of at least 400 feet, resting on the transition gneiss, and hornblende slate of this place. It likewise occurs at the Oosilah pass, under similar circumstances, capping the outer range of Ghàts below Suyapatam in the Bhagulpore district.

"The lower beds in both these localities assume a massive character and resinous or waxy lustre, indicating an approach to the steatitic or grey-wacke quartzose sandstone of Guidore, to which period they perhaps refer, being anterior to all the coal measure conglomerates, although it is difficult to fix the exact position of these quartzose sandstones, from the circumstance of their forming isolated mountain caps, uncovered by other rocks. It contains no useful minerals.

"*Conglomerates underlying Coal.* (*Old Red Sandstone?*)"

"These conglomerates form a hilly tract, extending south from Curracutta, in the Rajmahal district, as far as the country has been examined in that direction.

"The northern boundary of this formation is well marked by the Curracutta hill, a prominent double-peaked mountain, 900 feet above the sea, situated about five or six miles south-west of Mussinia. About a mile west of the lastmentioned village the coal measures insensibly disappear, and all traces of them are lost on a low ridge two miles distant, which is the only point in the Rajmahal hills where these coal measures are not bounded by trappean rocks.

"The conglomerates which here displace the coal measures consist of thick-bedded coarse sandstone, composed of gravel, sand, and various sized quartzose pebbles, imbedded in a fine argillaceous matrix. These coarse and thick beds alternate with thin-bedded, close-grained, flag-like sandstones, of a fine texture, varying in thickness from 12 to only 2 or 3 inches, succeeded, again, by coarse and thick beds of the same nature.

"After several alternations of this kind for the space of a mile or more (extending across the direction of the strata), the rock assumes a more uniform character and a reddish colour.

"Curracutta mountain consists of a mass of sienite, covered by hornblende slate on the one side, and by the conglomerates under description on the other. The disruptive mass is prolonged on the north side into a large trap dike, which has been traced for some miles.

"These conglomerates, resting on sienite and hornblende slate, terminate a few miles north of Curracutta mountain, forming a narrow wedge-shaped tract, dipping to the east, beneath coal measures.

"West and south of Curracutta the conglomerates expand, in the direction of the strata, into broad and lengthened ridges and valleys extending for several miles to Semanijoor, where they become covered beneath the secondary trap of the district.

"From the general aspect of the country to the south, it is presumed that it is composed chiefly of these conglomerates, extending towards the civil station of Soorcy, in which direction, according to information received from that place, coal measures again occur.

"From Curracutta to Semanijoor these conglomerates are undisturbed, presenting an uniform dip of about 20°, for a distance of five miles across the outgoing of the strata; but approaching Semanijoor, the strata there become invaded by and covered with outbursts of trap, which compose all the country lying to the north, except where small patches of altered coal measures occur.

"No fossils were found in this formation, the nature of which is therefore inferred merely from its position between the coal formation on the one hand, and the other trappean and slaty rocks on the other, as well as from its mineral characters, which differ very much from those of coal measure conglomerates.

"*Subordinate Beds.*—No carboniferous shale or clay iron-stone occurs in this conglomerate."

Such are Dr. M'Clelland's descriptions of his "Cambrian and Silurian Rocks," together with his "Old Red Sandstone." We have now to identify these deposits with similar strata in other parts, if possible; but, before attempting this, it is desirable to premise the following tabular summary of their principal characters:—

Table.

Old Blue Slate ..	Old Blue Slate, superposed by beds of quartz and talcose Slates.
Newer Clay-slate.	Newer Clay Slate, alternating with the following subordinate beds :— Blue compact Quartzose Breccia, veined, like marble, with white streaks, resembling Transition Limestone ; in beds of 5 to 50 yards in thickness, alternating with newer clay slate. Grey-wacke or Steatitic Sandstone ; consists of a quartzose sandstone, containing steatite and diallage of a peculiar greenish-yellow colour, resinous lustre, and splintery fracture ; alternates with newer clay slate. Rests on beds of quartz and talcose slates, which again rest on Old Blue Slate.
Transition Gneiss . .	Gneiss in fine and coarse-grained beds, alternating ; massive or in flags ; composed of quartz, more or less hornblende, lenticular flattened nodules of felspar, coarse garnet pebbles, and mica ; imbedded in a matrix of earthy half-crystalline felspar ; occurs sometimes in the form of sandstone flags, of a granular structure, slaty, quartzy, with more or less mica and hornblende ; alternating with coarse beds of the composition above described. It presents micaceous and hornblende schistose beds, and even small beds of calcareous breccia. Rests on primitive gneiss or primitive clay slate, and passes into sienite.
Sienite ..	Sienite, chiefly composed of crystalline, reddish-yellow felspar and hornblende, with a little quartz, the felspar predominating passes into "Transition Gneiss" ; veins gneiss along with trap.
Porphyritic Greenstone	Greenstone of a porphyritic structure, stratiform or massive, consisting of hornblende and quartz ; quartz disseminated in numerous crystalline points in the massive variety ; in flattened nodules, as above stated, in the stratiform variety. Alternates with strata of "Transition Gneiss."
Hornblende Slate ..	Hornblende Slate of a porphyritic structure, consisting of lenticular compressed nodules, and plates of quartz and hornblende. Underlying either the basis of coal measures, slaty quartz, or "Old Red Sandstone" conglomerate.
Slaty Quartz. .	Granular Quartz of a thick slaty structure, becoming massive below, and of a resinous or waxy lustre (indicating an approach to the steatitic or grey-wacke quartzose sandstone of Guidore). Capping the sub-crystalline and other trappean slaty rocks of this section ; thickness 400 feet.
Old Red Sandstone.	Conglomerates in thick beds, consisting of gravel, sand, and quartz pebbles, in an argillaceous matrix, alternating with thin beds of fine-grained sandstone, flag-like ; assuming, after a mile across the direction of the strata, a more uniform character, and reddish colour. Position, between the coal measures and older trappean and slaty rocks.

Such is a tabular view of these strata; and, looking for their extension to other parts, we cannot help being struck with the great resemblance that exists between the composition of the "Grey-wacke or Steatitic Sandstone" and "*Transition Gneiss*" of the Curruckpore and Rajmahal hills, and the steatitic sandstone which immediately overlies the sienitic and greenstone hills of Kalinghur and Adjighur, so minutely described by Jacquemont. With his "porphyritic stratum" which traverses this sandstone, we have nothing to do just now; but he particularly alludes to the *steatite*, which divides the strata of sandstone into layers, and enters into the arenaceous structure of the rock in parallel laminæ; the *red felspar*, in portions of a laminated structure; and rounded portions of quartz, with mica; presenting here and there spots of a violet colour.

Moreover, as regards the origin of these materials, Jacquemont, in describing the sienite below them, notices varieties in which "mica s'associent à l'Amphibole, sans jamais la supprimer entièrement; des roches de Felspath et d'Actinote, ou de Felspath et de Diallage douteuses, ici comme à Adjighur dans la nature de leurs éléments" (Tom. i. p. 431).

We therefore may, I think, reasonably infer that the sandstone of these localities, and the "Grey-wacke or Steatitic Sandstone" and "*Transition Gneiss*" of the Bhagulpore district, were chiefly derived from the red felspathic rocks, and that too, probably, of the same age, even if we doubt the identity of the formations. As to the presence of "garnet pebbles" in the "Transition Gneiss," that may depend on locality; as well as the eruption of sienitic and greenstone rocks. The "*Slaty Quartz*" rock, Dr. M'Clelland thinks, is allied in composition to his "Grey-wacke or Steatitic Sandstone."

Passing to the other side of India, viz. to the Southern Mahratta Country, we have here too, in the neighbourhood of Dharwar and elsewhere, a conglomerate, similar to the "Grey-wacke, or Steatitic Sandstone." Lieutenant Aytoun also gives a section of a hill about three miles south of Bhagulkote, which is composed of sandstone and schistose clay, alternating in very thick beds. In the valley between Yarkul and Bhagulkote, crystalline greenstone and green schistes alternate with each other in strata which are nearly vertical, and on each side of them are ranges of vertical strata of sandstone, consisting of jaspideous and quartz pebbles, with much felspar, in a sandstone cement (Aytoun); also in the bed of a watercourse at Kaludghee, Christie observed slates interlaminating with grey-wacke. Newbold also states that the sandstone overlying the granite between Gooty and Kurnool, which, at the former place, is red, and contains chlorite and actinolite mixed with the felspar, is composed of "white quartz pebbles, from the size of a filbert to that of

a man's head," a few of trap and hornblende, and of tough actinolitic felspar, also flinty slate, the very hardest parts of the hypogene and granitic rocks; but he saw no fragment of ordinary granite, or of gneiss. Going to the north, there is a decomposing conglomerate at Balmeer of the same description, the greatest part of the cement of which, as well as parts of the pebbles themselves, is composed of a chalk-white, fine, steatitic earth (Mm. Forbes). Of the existence of a green steatitic sandstone or grey-wacke in the Southern Mahratta Country, composed of greenish chlorite, red felspar, and quartz pebbles, there can be no doubt; and with reference to the presence also of "Transition Gneiss" there, Christie observes: "All the transition gneiss I have seen in Dharwar is weathered, closely resembling loose sandstone." The only "primitive gneiss" he appears to have met with was at the falls of Gairsuppa.

The same remarks, however, apply to the identification of these deposits with those of M'Clelland's "Cambrian and Silurian Rocks" of Bhagulpore, that I made with reference to the confusion which exists between the older metamorphic strata and the metamorphosed strata of newer formations. There is comparatively nothing definitely described respecting any of them, and it is evident that there are not only the metamorphic strata, and the "Cambrian and Silurian Rocks," provisionally so called, but also metamorphic rocks of the following group; all of which are at present so uncharacterised, that there is no possibility of finding out to which series the observations on such rocks apply. The slates of the older metamorphic rocks appear to be most extensive; the deposits of the "Cambrian and Silurian" follow; and those of the next series the least, by far, of all. Further than this we hardly know more than that such series exist.

Our last step is to identify the "*Old Red Sandstone?*" of M'Clelland, but this cannot be well done until the following series is described, which we shall provisionally call "Oolitic."

V.

Oolitic Series.

Tara Sandstone.

Kattra Shales.... { *Shales.* *Limestone.* *Coal.* }

Punna Sandstone.

Previous to entering upon a separate description of the members of this series, which has already been stated to be the most interesting in India, on account of its almost universal occurrence, its mineral resources, and its organic remains, it will be as well to premise a few

observations on the facts which have led to a knowledge of its existence, and of the parts into which it has been subdivided.

That tract of it which is most continuous and appears to have been least disturbed by volcanic influence, extends from the eastern border of the trap of Malwa, near Saugor, to the alluvial deposit of the Ganges near Mirzapore; and it is therefore to this that we must chiefly look for its typical characters.

Captain Franklin, who first explored this district, pointed out that, in travelling SW. from Mirzapore into Bundelkhund, two ranges of hills or escarpments are successively ascended, each of which terminates in a plateau. The first range is entirely composed of sandstone, presenting no argillaceous strata whatever in its composition; but the second range, which rises from the plateau of the first, and is also of sandstone, does present argillaceous strata, viz. in its upper part, which again pass into limestone on the plateau.*

Jacquemont, who followed Franklin, apparently with the description of the latter in his hand, recognised a third range of sandstone hills in Franklin's Punna range, which the latter appears to have regarded as merely an accidental elevation of the second plateau; and on ascending these, he observed that they were composed of fine-grained, reddish, and mottled or variegated sandstone, resting on the argillaceous strata, which accompanied the limestone of the second plateau. This range Jacquemont considered about 300 feet high.

Moreover, in a well from 36 to 45 feet deep, between Douzounepore and Puttrahut, he found small layers of anthracite between strata of compact limestone, the latter breaking with a conchoidal fracture, and presenting a dark, black-blue colour. These are his words:—"Le carbone, en quelques places, s'y resemble assez pour former de petites couches minces, qui ont tout-à-fait l'aspect brillant et la dureté d'Anthracite."

Lastly, Dr. Adam, who travelled across these sandstone ranges, states that at Lohargong the limestone is in a valley bounded on all sides by sandstone hills, which valley he compares to the bed of a lake, into which the Ken river enters on the south, and makes its exit at the northern border; and on leaving this valley to proceed southwards to Bellary, which is forty-five miles distant, he passed over a ridge of sand-

* Is this the limestone to which Captain Coulthard alludes (p. 226, *antè*), where he observes, "The eastern edge of this sketch [that is, the eastern boundary of the trap of Malwa bordering on Bundelkhund], as stated in the commencement of this notice, is where the thin covering of the lower lias lies on the upper portion of the new red rock series, viz. clays, marls, and calcareo-arenaceous sandstones, tender and often variegated, and it is desirable to note in particular that such is the case"? If so, and this should prove to be the "Intertrappean Lacustrine Limestone" between the two sandstone groups, we may have to give the former an oolitic age, and still further admire the sagacity of Franklin and Coulthard, who first assigned it to this period.

stone hills. This fact, if it were necessary, might be adduced to support Jacquemont's observation, that there is a sandstone formation above the shales and limestone. Both Franklin and Adam allow that the limestone rests on the sandstone of the second plateau, but *they* go no further.

Let us now turn to a section afforded by the same tract of sandstone in the neighbourhood of Bidjighur, which is about one hundred and fifty-five miles east of Lohargong, on the river Son, where the strata dip to the north, as in Bundelkhund, and present a scarped surface towards the south, which is but a continuation of that at Bellary ; where, also, I might have mentioned that Dr. Adam, after he had descended the ridge between this place and Lohargong, again saw among quartz rocks (altered sandstone ?) in vertical strata, some which had "a peculiar striped arrangement in the mass, and in colour, lustre, and compactness not unlike the limestone of Lohargong." But to return to our subject. Mr. Osborne, who, upon the information communicated by Mr. Heydey, respecting the existence of coal near Bidjighur, was sent to examine that neighbourhood, states, that in going from Bidjighur to the river Son, by the Ek-Poway Ghàt, he saw limestone strata of all colours, and some of a lithographic structure, of which he sent specimens to Calcutta. Afterwards, he picked up black portions of limestone, which is better seen *in situ* in a nulla near Markoonda ; and in the bed of the Son, pieces of coal ; but he did not see any coal-strata there. One of his sections of the Son shows " limestone" cropping out under 500 feet of " quartzy sandstone," and below the limestone " grey-wacke." Altogether the following section, from above downwards, is computed from his observations :—

Sandstone, 60 to 80, and 700 feet; shale, with exudations of petroleum ; sandstone interlaminated with shale ; flinty slate ; sulphate of iron ; limestone of all colours, some lithographic in structure.

This gives 700 feet of sandstone above the shales and limestone, and when we follow the banks of the Son onwards to Rhotasghur, in the zillah of Shahadabad, we find it still thicker. Captain Sherwill, who surveyed this zillah, writes :—" One of the precipices in the fort of Rhotas I found by measurement to be 1,300 feet, a sheer mass of sandstone, without a bush or tree on its surface." And afterwards, in alluding to the limestone on the eastern scarp of this sandstone table-land, he states, that it forms "an unbroken bed from the foot of the fortress of Rhotas to the village of Dowdand, a distance of thirty miles north"; and, still " proceeding in a north-westerly direction, at the distance of thirteen miles, we meet with the same limestone in the valley of Soogrea-Khoh, at the depth of 1,000 feet below the summit of the table-land." The general appearance of this limestone is of a dark slate colour, breaks with a conchoidal fracture, strikes fire with

steel, is impalpable in texture, and quite free from any exuviæ. Portions of it were sent to Calcutta for trial in lithography. In a few cases it was nearly black, also of a pale yellow or buff colour.

Under the fortress of Rhotas, and in other places, Captain Sherwill also states, is the following section :—"Sandstone, 1,000 feet; indurated potstone, 30 feet; dark schistose rock or ore of alum, 10 or 12 feet."

There is this important distinction, then, between the sandstone of the Ghàts or escarpments which lead to the table-land of Bundelkhund near Mirzapore, and the escarpment of the sandstone at Rhotasghur, viz. that one has the shales at the top, and the other has them at the bottom.

Passing still further eastward, and leaving the valley of the Son, together with the great continuous sandstone tract of Bundelkhund, we, according to Captain Sherwill, first meet, in the zillah of Bahar, with granite hills capped with sandstone; then at Gya others which are completely denuded; and on arriving at the boundary of the zillah of Monghyr, granite peaks, projecting from amidst hills of quartz.

We have now reached that point on the Ganges, about 60 miles south of which, that is from Soorajghurrah, is the Curhurbalee coal-field which rests on M'Clelland's "Old Red Sandstone," and forms one of the great coal deposits in this part of India; and although we are not, in the present state of our knowledge, able to connect it with the carboniferous shales of Bundelkhund, through Bahar, yet the latter may be traced from the banks of the Son to those of the Koyle at Palamow, which, again, is close to the western extremity of the Damoodah valley, where the greatest number of these coal deposits have been discovered, and not far from which, too, is the coal-field of Curhurbalee.

Thus the type of the Oolitic Series above tabled would appear to be established.

That keen, talented, and intelligent traveller, Jacquemont,—who knew at once for what to seek, had the ability to discern, and was never at a loss to describe,—during his short visit to Bundelkhund, on his way from Calcutta to Delhi, first completed this series. Franklin, a brother of the great Arctic voyager, had gone so far as to show that the shales and limestone overlaid the sandstone, but Jacquemont added the Punna range of hills to the latter in 1830. Subsequently Malcolmson, in 1837, showed that sandstone overlaid shales and limestone in Southern India,*

* At p. 298, *antè*, the Rev. W. Hislop notices that he has learnt "from Mr. S. Schlagintweit, that the sandstone and inferior shales of Southern India are unconformable." Dr. Malcolmson, p. 7 *antè*, states: "As far as I have observed, the sandstone always rests conformably on the schists, although, from its jointed structure, it occasionally, when elevated, appears to meet the subjacent rock at a more or less obtuse angle." Dr. Christie and Captain Newbold, pp. 341 and 353, *antè*, respectively state, that the sandstone in the Southern Mahratta Country rests un-

and lastly, Newbold proved, by the following section of the Moodalaity pass, near Kurnool, from above downwards, that the lower sandstone also existed there :—

Section of the Pass of Moodalaity (Newbold).

	Ft.
Compact light-coloured sandstone passing into quartz rock and conglomerate.	120
Beds of compact limestone, of light tints of green, red, and buff, often lined with dark red jasper, and light-coloured cherts	310
Calcareous and argillaceous shales, usually reddish, and liver-coloured, passing into white; surfaces of laminæ often covered with light green (chloritic ?) flakes........................	50
Laminar sandstone, micaceous scales between the layers.	
Massive sandstone.	

Previous, however, to all these, Captain J. D. Herbert (1828) stated, respecting some coal which was found by Lieutenant (now Colonel) Cautley, in the vicinity of Nahn, about forty miles ENE. of Umbala, in the Sub-Himalayan range, that it exists in a formation of fine sandstone above, shales and limestone in the centre, and conglomerates below; that this is the "Coal Rock" of India; and he further adds: "This sandstone is, I think it almost certain, part of an extensive secondary formation, which on the one hand includes the sandstone hills of Sylhet, and on the other the saltiferous range of Lahore."

Lastly, in 1837 Captain (now Colonel) Grant's valuable paper on the Geology of Cutch appeared, and in it also may be traced a similar series to that of Bundelkhund, as the following section, from above downwards, compiled from his descriptions, will show:—

Sandstone, coarse and soft, or compact and crystalline.
Slate-clay of vast thickness, alternating with limestone of a lithographic structure, and grey colour, also occasionally with slaty sandstone.
Thin beds of coal intermixed with blue clay or shale, thick beds of sandstone alternating with slate clay.

Having thus endeavoured to show the general distribution of the series above established, let us now proceed to the description of its members separately.

Tara Sandstone. (II. J. C.)

This name is derived from the Tara Pass or Ghàt, which leads from the alluvial deposit of the Ganges, about ten miles SW. of Mirzapore,

conformably on the transition rocks there, "namely, the clay-slates, grey-wacke, limestone, &c." Lieutenant Aytoun, p. 391, alludes to a section at Bhagulkote, which, to use his own words, "places beyond all doubt the alternation of the schists with the quartz sandstone," in the Southern Mahratta Country.

to the summit of the first sandstone range of Bundelkhund, the route taken by Franklin and Jacquemont, who have described it.

Synonyms.—New Red Sandstone (Franklin and Jacquemont). Old Red Sandstone? (M'Clelland).

From Franklin and Jacquemont we learn that the Tara Sandstone is composed of fine grains of quartz, with a little mica, which is held together by an argillaceous cement of a red colour, the latter varying in intensity. Its structure is "rather friable than compact," but in many places is sufficiently hard for architectural purposes. It is horizontally stratified, but presents nothing else, except a few nests of red clay here and there, to disturb its uniformity and continuity.

Towards its upper part the grains become extremely fine, and the colour of the mass changes to green; after which it passes into argillaceous (and talcose? Jacquemont) strata of green and red colours alternating, but the latter still continues to predominate.

The thickness of this deposit has not been stated. It could not be determined at the Tara Pass, on account of the base of the hills being under the alluvial deposit of the Ganges. But Jacquemont remarks, on the authority of Captain Drummond, that the summit of the Tara Ghàt is 300 metres (900 feet in round numbers) above the valley of this river.

No fossils have been found in this sandstone, and no minerals, beyond the red oxide of iron which colours it.

At the pass of Moodalaity mentioned, Newbold describes this, or the lower sandstone there, as "laminar" and "micaceous," passing downwards into "massive sandstone," and above into shales of white and red colours, with green flakes of chlorite.

In Cutch the Tara Sandstone is not noticed by Grant, probably from the insufficient elevation of the masses; and his boring experiment appears to have only reached its upper part, if even that.

Identification with "Old Red Sandstone" *of M'Clelland.*—This consists in the great simplicity of composition in both; the absence of crystals of red felspar, which may be inferred from the silence of Jacquemont and M'Clelland on this point, and the situation of this formation immediately below shales and carboniferous deposits in both instances, which are evidently connected with each other. The presence of conglomerates at the Tara Pass is not seen, perhaps because they may be underneath the alluvial deposit of the Ganges; but the texture of the sandstone is stated by Jacquemont to become finer in ascending, and therefore probably becomes coarser in the opposite direction.

With reference to the lower limit of this sandstone, Jacquemont, in alluding to the difference between it and that of Bundelkhund reposing

on the sienite of Bisramgundj Ghàt and Adjighur, close by, states:—"Malgré l'extrême ressemblance oryctognostique dont je viens de parler, j'incline à croire cependant, que les grès du Tara Ghàt et du Kuthra Ghàt appartiennent à une autre formation, et que cette formation est celle du *New Red Sandstone;* mais je soupçonne que le grès rouge ancien recouvre les Sienites du Bisramgundj Ghàt et de toute cette partie des montagnes de Bundelkhund."

He also states that he did not see the junction of the two, but that this might have been concealed by superficial detritus; while Coulthard observes of the sandstone at the opposite extremity of Bundelkhund, near Hirapur, between Saugor and Punna, that the granite is "capped by heaps of ferruginous conglomerate, which conglomerate is connected with a stratum of iron ore, on which the 'New Red Sandstone' is seen to repose:" this sandstone, again, becomes covered with red and variegated shales in approaching Saugor, followed by the superposition of more sandstone, which here and there, as in a hill at Bhilsa, presents the flat top and scarped sides, which we shall by-and-bye find to be characteristic features of the upper member of this series.

Should this identification of the sandstone of the Tara Ghàt and the "Old Red Sandstone" of M'Clelland be correct, I would adopt the term of "Tara Sandstone" for both, particularly as the latter is provisional.

Kattra Shales. (H. J. C.) . . { *Shales.* / *Limestone.* / *Coal.* }

This term has been taken from the Kattra Ghàt, which is the name of the pass leading from the first to the second plateau of Bundelkhund, where Franklin and Jacquemont saw respectively the Tara Sandstone passing into argillaceous strata; limestone on the second plateau; bituminous shale cropping out in the glens of the Bajin river; and anthracite in a well; so that representatives of all three sub-divisions of this member of our Oolitic series are thus found to exist in Bundelkhund, though more developed elsewhere.

Synonyms.—Clay-Slate Formation (Voysey). Argillaceous Limestone (Malcolmson). Laminated Series or Upper Secondary (?) (Grant.)

Shales.

These, in their purest state, are almost entirely composed of indurated clay, and arranged in strata of all degrees of thickness, varying from laminar to massive, and of all kinds of colours. When mixed with other substances in company with them, which is frequently the case, they may be calcareous, bituminous, quartziferous, micaceous, talcose,

or chloritic. They pass into the sandstone both above and below them, and alternate with it in some places, to such an extent that "the cascade of the Ranj river," in Bundelkhund, according to Franklin, "shows a series of sandstone interstratified with slate clay, 390 feet thick." They are also interstratified with limestone and coal, either together or separately, and though sometimes almost deficient in both, they chiefly derive their importance from the presence of one or the other of these deposits. There is, therefore, little to be said about these shales by themselves, and their geographical extension will be best considered in connection with the other members of the series.

Respecting their fossiliferous contents, too, *per se*, there is little known. Dr. Bradley, in a letter on the sandstone at the northern border of the trap, writes:—"In the shales north of Ellichpoor was the only place where I found impressions of leaves, plants, and ferns. The ferns appear to belong to *Pecopteris*. In one, however, the pinnules differ. Stems, leaves, reeds, and matted leaves abound." But it is in connection with the coal strata, or overlying sandstone of this series, that the fossils of the shales have been chiefly found, and it is therefore with the descriptions of these that they will respectively be noticed.

Limestone.

The principal characters of the limestone are its uniform lithographic texture, solidity, conchoidal smooth fracture, and hardness; dendritic surfaces; smoky grey colour, passing into dark smoky blue; and parallel thin stratification.

Everywhere it presents these characters in Cutch, near Neemuch, Bundelkhund, on the river Son, near Bidjigurh, and at Rhotasghur, Ferozabad on the Bhima, Kaludghee in the Southern Mahratta Country, on the middle third of the Kistnah, and as far south as Cuddapah, in the Madras Presidency. Grant, Dangerfield, Hardie, Franklin,* Jacquemont, Sherwill, Osborne, Meadows Taylor (P.MS.), Malcolmson, Voysey, and Newbold, have respectively described this limestone in

* The tract of limestone in Bundelkhund described by Franklin should now, I think, be considered a part of the Intertrappean Lacustrine Formation, and if so, the question which I have already suggested, p. 652, foot-note, then arises; viz. whether or not it belongs to the Oolitic Series? Franklin, as will presently be seen, found fossil wood and stems of ferns in it; and Hardie, who notices the same kind of limestone about Neemuch (pieces of which have frequently been brought to me, proving that it consists of a thinly stratified, fine deposit of a lithographic structure, with dendrites on the planes), also found impressions in it very like *Zamites*, and the remains of a shell, chiefly the border, which in every way corresponds to a full-grown *Unio Deccanensis*, but which he assumes to have been "a variety of Pecten." He only saw "one variety of limestone," characterized in every position where he had an opportunity of examining it "by a *similarity* or rather *identity* of *organic remains*";—the italics are his;—and this limestone "*overlies* the sandstones and sandstone-slates (Asiatic Research. vol. xviii. pt. 2, p. 42).

different parts of India, and all agree in giving it the characters above mentioned, while the Society's museum verifies most of their accounts by specimens of this formation from several of these places.

It differs, however, when departing from its genuine composition, just as the shales differ which interlaminate it, the coal strata, and the sandstone, in being more or less argillaceous, bituminous, or quartziferous; of different degrees of hardness, coarseness, and friability of structure; and of all kinds of colours, streaked and variegated; but I am inclined to think that the latter only occurs where it has been exposed to heat. It is sometimes quite black. Lucullite occurs in it between Dachapilly and the Kistnah (Voysey), near Bidjighur on the Son (Osborne), and in several other places.

It is occasionally veined and interlined with jasper and light-coloured cherts, which, projecting from it under weathering near Cuddapah, give it a scabrous appearance (Newbold); also contains drusy cavities, calcedonies, and cornelian, north of Nagpore (Malcolmson). Small crystals of quartz occur in the lithographic forms, which render them more or less unfit for lithographic purposes; indeed, the presence of siliceous matter generally, more than the want of uniformity of structure, seems to render this limestone too hard for lithography; but I question, among its infinite varieties, whether there is not some place which would yield forms as serviceable as those imported from Europe. The argillaceous varieties are frequently flaked with green chlorite; steatite of a white chalky nature is found in thin beds in it, in the Keymor range (Sherwill), and in the neighbourhood of Cuddapah, where it also passes into the compact form of "French Chalk," and is cut into pencils, which are used for smoothing lime-plaster, and writing on cloth prepared for the purpose (Newbold). A small detached hill at the fort of Rhotasghur is almost entirely composed of a dark blue potstone, which, with the small veins and beds of serpentine that are found in low hills in the zillah of Bahar (Sherwill), are not improbably associated with this limestone.

It is of a snow-white colour, and traversed by chlorite schiste in the bed of the Nerbudda between Lamaita and Beragurh, near Jubbulpore (Franklin); and beautifully granular and crystalline, with red and white steatite intermixed at Khorari, six miles north of Sitabaldi, near Nagpore (Jenkins). It also exists in many places in the form of granular, saccharoid, white marble; but in all these instances appears to be metamorphosed by heat. Jacquemont mentions, at Alwar, about sixty-five miles north-east of Jaipore, thin beds of amphibolic limestone (Hemithrene, Bgt.) of a black colour, alternating with quartz in vertical strata, the latter becoming subordinate; and at Bessona (the first town in the territory of Jaipore coming from Alwar) a granular, white

saccharoid marble, in some of which green amphibole and flakes of amphibole and talc are also disseminated ; also at Rajghur, seven miles west of Nusseerabad, where mica is added to the amphibole. Thus we have all the chief minerals of the mica and hornblende families in, and in connection with it, but this, as I have before stated, is under a metamorphosed state.

Wherever this limestone is situated throughout India, it has undergone more or less disturbance and denudation. Greenstone and trap appear to be the principal agents which have been engaged in the former, for these almost always accompany it, and are almost the only igneous rocks which appear to have invaded it. Yet it frequently rests on granite, by which it appears to have been upset more than penetrated, and in the Southern Mahratta Country the older metamorphic schistes have been forced up through it ; but the only instance recorded of its being veined and enveloped in granite is at Kamari, near Ramteek, in the hills NE. of Nagpore (Jenkins and Malcolmson).

It is not unfrequently brecciated to a great extent, by fracture and reconsolidation under a cement of calcspar. A remarkable instance of this exists near the village of Guddunkeeree, in the Southern Mahratta Country, where the dike, so to speak, or edges of the strata brecciated, run along the plain NE. by N. and SW. by S. Lieutenant Aytoun, who describes it, states that it is composed on one side of rhombohedral calcspar, and on the other of breccia. On the WNW. "not less than 20 yards" of pure calcspar exist in contact with the unaltered limestone of that side; and on the ESE. side the unaltered rock gradually becomes more and more brecciated, until it passes into the calcspar. The strata are, of course, vertical, and the calcspar would appear to have been crystallized from a watery solution.

This limestone is frequently denuded of its overlying sandstone and shales in Southern India, and in this state is not uncommonly covered by trap, as near Ferozabad on the Bhima (Meadows Taylor, P.MS.).

Newbold gives this limestone a thickness of 310 feet at the pass of Moodalaity, near Kurnool; Meadows Taylor from 10 to 30 feet on the Bhima, with strata from 2 inches to 2 feet thick (P.MS.). Dr. Bradley mentions a sandstone hill north of Ellichpore capped with 6 feet of limestone (P.MS.). The Gupta caves of Bahar, about forty or fifty miles NW. of Rhotas, are in limestone, and their entrance is stated to be from 10 to 12 feet high (Sherwill). Much more definite information, however, on this head, is required, to give an idea of its general thickness ; which, probably, its interstratification with the shales, or its position generally, where exposed to view, may have rendered difficult to obtain. In no part mentioned does it appear to be so thick as at the pass of Moodalaity.

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Geographical Extension.—If we allow the white crystalline marble generally of India to be metamorphic strata of this limestone, which I think we must do, until otherwise proven, then we should have this form of it in the Girnar of Kattywar; the lithographic or original form in Cutch; the white marble about Oodeypore; the lithographic form between Neemuch and Chitore; the white marble northwards, in the neighbourhood of Nusseerabad, Jaipore, Bessona, and Alwar; that of Mokrano in the Jodpore district, from which the white marble of the Taj Mahal was chiefly taken; a narrow strip in its original state one hundred and fifty miles long in Bundelkhund; more again about Bidijghur and Rotasghur on the Son; in the state of white marble, in the bed of the Nerbudda near Jubbulpore; also the same at Ramteek, in the hills N E. of Nagpore; along the lower parts of the Wurda and Pyne Gunga towards their confluence, where they form the Pranheeta; thence to the Godavery, and along the latter and its neighbourhood, more or less, to the vicinity of Rajamundry; in the district of Shorapore, on the Bhima; of every variety of colour, and greatly disturbed and broken up about Kaludgee, in the Southern Mahratta Country; along the Kistnah, from Kurnool to Amarawattee, and more or less all over the triangular area formed by the latter place in the east, Gooty in the west, and the Trepatty hills in the south; south-east of the latter place a narrow valley extends through it for 150 miles, where its strata are in many places vertical (Malcolmson). As yet it has not been noticed in the southern part of the peninsula, either in its original or metamorphosed state, any more than the sandstones and shales which accompany it; at the same time its absence there is by no means determined, for there is metamorphic limestone in the district of Tinnevelly, as has before been stated, which closely resembles that from the neighbourhood of Nagpore; but then all metamorphic limestones are so much alike, that, without more information than their mere locality, they only indicate places which may deserve further examination.

Minerals.—Galena in several places in the Cuddapah beds (Newbold); and Dr. H., in Voysey's journal, just after mentioning the limestone, states, that in a branch of hills south of Cuddapah, which runs east and west, he found "small veins of plumbago." This would be interesting if found in the limestone, since, as before stated, this mineral occurs in the metamorphic limestone of Tinnevelly and Ceylon (Major General Cullen).

Organic Remains.—Captain Franklin states, that at Nagound (Bundelkhund), in the bed of the Omeron river, where the lower and central beds of the limestone are exposed, "fragments of fossil wood and fragments of stems of ferns" are seen in them. He also gives a figure of a "gryphite shell," which, however, is too indistinct to be of any

use; yet he, partly upon this, founds his opinion of the identification of this limestone with the Lias.

There is a cast of a large turbinated shell, like that of *turbo* or *pleurotomaria*, in the Society's museum, which was found by Captain Nicolls, who presented it, ten miles NE. of Saugor. It is composed of calcspar. This is close upon the limestone of Bundelkhund.

Writing of this limestone near Neemuch, Dr. Hardie states that the organic remains in it are numerous, and then adds that one kind, when half exposed in the rock, appears in the form of a succession of cylindrical convex bodies, the length of which varies from 1 to 2 inches; they taper to a point, and frequently seem minutely ramified at both extremities. In one or two instances he observed the termination of such bodies to be in the mass itself, and in such cases they had obviously been arranged in bundles or fasciculi. In other instances these cylindrical bodies appeared to send off anastomosing branches, which unite them together. They do not differ in composition or colour from the limestone in which they are found. He also mentions "longish tapering canals," and another fossil body, shaped like a pear bent upon itself; one of his figured fossils very much resembles the impression of a *Zamites*.

Newbold also mentions tubular and elliptical cavities in the limestone near Kurnool, and near Cuddapah, microscopic bodies of a spheroidal shape and multilocular structure, in the chert, which is imbedded in the limestone.

In the Shorapore district its upper surface in many parts presents a number of conical cavities from 0 to an inch deep, and about half an inch wide at the orifice; they are sometimes so close together as to form a honeycomb appearance, and some seem to have a spiral form, which is indicative of their having been fretted out by grains of sand agitated by the wind (Mm. Meadows Taylor).

Little or nothing fossil, then, has yet been found in this limestone, to determine its age or position geologically in India; and even in Cutch, where so many organic remains exist in the shales accompanying it, no fossiliferous peculiarity has been assigned to it; nor can we expect to find many in it, for in its purest form it appears to be always subordinate to the shales, and then possesses a compact, fine, lithographic texture, which is seldom, I think, accompanied by many organic remains.

The absence of fossils in this limestone, however, is of little consequence, since, in the shales with which it is interlaminated, abundance both of marine and fresh-water have now been found; the former sufficient in number and species to enable geologists to place the shales of Cutch among the lower oolitic deposits. And from the corre-

spondence of the latter, together with the Cutch sandstone, in mineral detail, relative position, and physical features, with the shales and upper sandstone of India generally; as well as the proximity, if not continuity, of these formations in the two countries, I have placed them all provisionally in this series.

The fossils from the shales in Cutch, which are figured in Colonel Grant's geology of that province, consist of impressions of plants and shells:—Lycopodites, Ferns, Reeds, Zamites. Conchifera, Terebratula, Ostrea, Pholadomya. Ammonites, Belemnites, and a portion of the bone of a Saurian Reptile. (See descriptions of these *antè*, pp. 444 to 449 inclusive; also those given by Colonel Sykes, pp. 465 and 466.)

Coal.

Before entering upon a particular description of the coal strata, which appear to be most developed in Eastern India, west of the Hooghly and Ganges, it is desirable to give further proof of their claim to a place in our Oolitic Series, and this can only be done in the present state of our knowledge by showing the connection of the latter with the carboniferous shales of Bundelkhund.

It will be remembered that Franklin found "black bituminous shale" cropping out "in all the glens" on the north-western side of Bundelkhund, "particularly in that of the Bagin river"; that Jacquemont found anthracite in the side of a well near Rampore; and that on the southern side of this sandstone tract, Osborne found petroleum exuding from shale, with pieces of coal in the bed of the Son near Bidjighur; that, about forty miles east of this place, the Son is joined by the Koyle, the banks of which are, according to Sherwill, composed of sandstone similar to that in which the "Rajhurrah coal mines" are situated, "eighteen miles from the Bahar boundary"; and that fifty miles up the same river is Palamow, which, with its neighbourhood, has been the site of several coal operations; while about thirty miles SE. of Palamow, again, is the source of the Damoodah, at which coal has been seen to basset; and here and there eastwardly all along the valley of this river to Burdwan, where I believe the coal deposits of this part of India were first discovered, as well as the vegetable impressions (ferns) referable to the Oolitic Period. Lastly, the latter being identical with some lately discovered by the Rev. Mr. Hislop in the sandstone near Nagpore, which is that about to be described as forming the upper member of the Oolitic Series of India, we could not have a much more direct chain of evidence than this, in proof of the connection which exists between the bituminous shales of Bundelkhund, and the great coal deposits west of the Hooghly and Ganges, and of their containing fossils belonging to the Oolitic Series generally.

Carboniferous Deposits of the Oolitic Series in Bengal, West of the Hooghly and Ganges.

These consist of coal, shale, and sandstone, but of no limestone, so far as has been observed; and they appear chiefly to occupy the depressions of the granitic and metamorphic rocks, which form this part of India; becoming exposed in the banks or beds of watercourses or rivers which have passed through them, or in escarpments which have been produced by upheaval of the rocks on which they were deposited. Perhaps the most powerful agents of the latter have been the trappean effusions, which will be described hereafter.

The coal occurs in strata from an inch or less to 9 or 10 feet in thickness, interstratified with shale and sandstone, the whole possessing a dark black or blue colour, of a greater or less intensity. There is no particular order in this interstratification, either in the thickness of the strata, or in the kind of strata which follow each other. The coal may be between two argillaceous strata, or between two sandstone strata, or have a stratum of either on either side; and the shale and sandstone strata may vary in thickness; but the thickest beds of the latter far exceed those of the former. Sometimes the coal is close upon the surface, at others it is covered by a variable thickness of shale or sandstone. This probably depends on the amount of denudation which the strata may have undergone. In one section of a shaft sunk at Palamow by Mr. Homfrey, 200 feet of sandstone superposed the first bed of shale and coal, which occupied 6 feet 1 inch, and then followed a stratum of 30 feet of sandstone before the next shale appeared. At Singra in the same neighbourhood, 20 feet of sandstone superposed a bed of coal and shale 2 feet 2 inches thick, followed by a bed of sandstone of 18 feet, and afterwards thinner beds of coal, shale, and sandstone, for 20 feet 10 inches, succeeded by a bed of sandstone of 60 feet. At China Coory, also, in the vicinity, clay and shale, 7 feet 6 inches first, was followed by a bed of sandstone 85 feet thick; at Ranigunge, sandstone 24 feet 6 inches, shale 39 feet, and then coal. In the computation of the section of the Curhurbalee coal field by Dr. M'Clelland, there are altogether 800 feet, of fine and coarse-grained, micaceous sandstone with conglomerates (the former prevailing) between the upper and lower groups of coal, shale, and sandstone strata.

Some of the coal measures are very shallow, from denudation or intrusion of igneous rocks, others are deeper. One shaft sunk by Mr. Homfrey at the mines of Ranigunge reached 210 feet, passing through seventeen beds of coal, none of which were more than 16 inches to 3 feet in thickness, and of inferior quality. As, however, it is not my purpose here to give a summary of all the shafts and sections of the coal

measures that have been made in these districts, but to point out their position generally, their development, and their geological relations, I shall conclude what I have to offer on them in this part of India by inserting Dr. M'Clelland's excellent account of the coal-field of Curhurbalee, which will serve as a typical description for the whole.

The deposit of which this is a continuation "extends from the Damoodah coal-field north-west, along the valley of the Barakar to Curhurbalee, where it rests immediately on crystalline rocks, and is distinguished by the numerous valuable beds described in this report under the head of Curhurbalee coal-field. It also extends at intervals (the particulars of which have not yet been surveyed) from the Adji valley north into the Rajmahal hills; where it is in one place found resting on conglomerate sandstone [Dr. M'Clelland's provisional 'Old Red Sandstone,' our Tara Sandstone, provisionally], and a complete series of Silurian and Cambrian Rocks."

"*Curhurbalee Coal-field.*"

"This coal-field surrounds the village of Curhurbalee, Pergunnah Curruckdyah, and is situated sixty geographical miles south of the Ganges, at Soorajgurrah. The coal-field is bounded on the northern and eastern sides by fine table-lands, composed of gneiss (villages of Suliah, Bissumpore, Mohunpore, and Dundeedee).

"The southern boundary is imperfectly made out, the coal measures being cut off in this direction by quartz dikes and sienite (Buddeah, Gophai, and Lopsahdee villages).

"The western boundary rests on mica slate at the village of Peppratahn.

"The coal basin is four miles from east to west, and two from north to south.

"The coal measures are thrown up in tabular-shaped hills, which traverse the basin from east to west. The south-western declivities of these correspond with the gentle dip of the strata, while the north-western declivities consist of broken escarpments, formed by the edges of the uplifted strata.

"The lowest level of the coal basin is 800, and the highest 900 feet above the sea.

"The upper series of the coal measures, where they are exposed in the sections formed by the Sookneid rivulet (on the northern side of the basin), are as follows:—

"Sandy slate, clay varying in thickness from 10 to 50 feet.
"Compact claystone passing into clay ironstone, 10 to 20 feet.
"Slaty sandstone with mica.
"Slate clay, with thin beds of coal and shale, varying from 50 to 500 feet.
"Fine sandstone of uncertain thickness, with thin beds of coal and bituminous shale.

"The lower series of rocks composing this coal-field consists of hard thick-bedded sandstones, composed of earthy felspar, enclosing fine and coarse quartzose nodules, from the size of grains of sand to that of small pebbles.

"This conglomerate rests on gneiss, or in some places on mica slate, and is in places intersected by trap and quartz dikes: it alternates with beds of coal, bituminous shale, and clay ironstone, in the following order:—

"A bed of bituminous shale occurs sometimes, either alone, or in connection with a thin bed of clay ironstone.

"In the latter case it is succeeded by a second bed of bituminous shale, followed by a bed of coal, which is again succeeded by another bed of shale.

"It often happens that a similar repetition of shale, ironstone, and coal occurs two or three times in succession, with a vertical section of 50 to 100 feet.

"When clay ironstone is not present, a bed of hard ferruginous sandstone usually occupies its place.

"The whole series of sandstone, coal, bituminous shale, and clay ironstone, are represented in the annexed computed vertical section, in order to show the alternation of the several beds, which are disposed in strata, dipping towards the centre of the basin, at angles varying from four to twelve degrees with the horizon.

"The relative proportion of each member of this series to the general thickness of the whole, is as follows:—

	Ft.
"Slate clay, arenaceous shales, &c. forming the upper measures........	500
Sandstone conglomerate....................................	1,700
Coal, 20 beds, total thickness..............................	92
Bituminous shale, 44 beds, including under-clays (which mean the same thing), total thickness....................................	54
Clay ironstone 24 beds, total thickness............................	16
	2,362

"The whole thickness of the upper and lower series of coal measures, both taken together, may therefore be estimated at 2,362 feet, as shown above, as well as in the computed vertical section. No limestone occurs in this coal-field, nor have any fossils been found, either in the sandstone, shales, or slate clay; but when the coal-beds are once opened, sufficient fossil remains will then probably be found to throw some further light on the subject."

Leaving this district, and proceeding westwardly from the neighbourhood of Palamow, where many shafts have been sunk, coal has been seen about sixteen miles south of Chergerh in the district of Singrowla

(Franklin); thirty miles E. of Sohajpore, at the confluence of the Tipan and Son (*id.*); at Jubbulpore, in digging a well, more than thirty-five years since (Herbert); thirty-three miles south of Hoshungabad, on the road to Baitool (Finnis); and at Shapore in the same neighbourhood, discovered by Captain Ouseley (*id.*). In the Mahadewa hills, a continuation of the Satpoora range, one hundred miles due north of Nagpore (Mm. Jerdon); also by the late Dr. Walker ten miles from the confluence of the Godavery and Pranheeta, with bituminous shale, limestone, and sandstone above it, on all sides; and by his people in the form of anthracite in micaceous sandstone in a seam 3 feet thick at Duntinapelly, twenty miles from Sangaum, which is sixty-five miles west of Chinnoor. Dr. Bell, who has also been conducting a boring experiment at Kotah, in the same neighbourhood, has kindly favoured me with the following interesting and valuable section of this locality, from above downwards:—"Conglomerate of no great thickness; sandstone in hills from 50 to 500 feet in height; argillaceous limestone, 9 feet; bituminous shale, ¾ inch; argillaceous limestone, 1 foot; bituminous shale, 4 inches; fibrous carbonate of lime, impure limestone, and blue clay rock, 8 inches; bituminous shale 2 feet 1 inch; laminated sandstone, 8 feet ¾ inch; bituminous shale, 1 foot 6 inches; fibrous carbonate of lime, 1 inch; bituminous shale, 1 foot 3½ inches; impure limestone, 5 feet 3¼ inches; black arenaceous clay, 3 feet 6 inches; sandstone, 23 feet; clay, 7 feet 6 inches; sandstone, 2 feet; clay shale, 1 foot 9 inches; limestone, 1 foot 8 inches; clay shale, 12 feet; red marl, 27 feet; and limestone, which was only penetrated to the extent of 2 inches." Lastly, the late Captain Kittoe has given sections of coal strata at Talcheer and Ungool in Cuttack, where the coal is found within 13 feet of the surface, which, from the micaceous sandstone that accompanies it, is, in all probability, part of the formation we have just been considering. In the oolitic sandstone of Cutch it was long since discovered by Colonel Grant.

Under the head of "Garrawarra," which is a town on the south side of the Nerbudda, about eighty miles above Hoshungabad, Ansted, in his "Elementary Geology," p. 541, states:—"On the Seeta Rewar river, there appear to be three beds [of coal], whose thickness is 20, 40, and 25½ feet respectively: these are covered with a thin bed of sandstone." Again, under the head of "Jubbulpore," he states:—"At nine miles from the station there is a large bed of first-rate quality, many yards thick, crossing the bed of the Son." The nearest part of the Son to Jubbulpore is forty miles distant, so this would appear to be the largest bed yet discovered. No authorities are given.

Geographical Extension.—The extremes of this coal formation, so far as have yet been discovered in the tract of India under consideration,

including the angular portion beyond Delhi and Ferozepore, are : the confluence of the Godavery and Pranhecta in the south, in about 19°, and Nahn, in the Sub-Himalayan range, in about 30° 30″ N.; Cutch Bhooj in the west, and Burdwan, about fifty miles NW. of Calcutta, in the east. But by far the greatest number of places in which it has been noticed, indeed I might say almost the whole, with the exception of the northern and southern extremes, are between the 20th and 25th parallels of latitude; and here the greatest development of this formation appears to be in the east, expending itself out towards the west. In the districts of Burdwan, Birbhoom, Monghyr, Ramghur, and Palamow, its great development appears to be at the expense of the upper and under sandstone, together with the limestone, for these are frequently unrecognisable, particularly in the first-named districts, where the coal formation appears to rest chiefly on the granitic or metamorphic rocks. There are many other places, no doubt, between Bengal and Bahar on the north and east, and Orissa and Berar in the south and west, respectively, where this valuable mineral may be found; but it remains for future explorations to prove it more satisfactorily, and to point out whether the coal is so situated, with respect to other minerals or water carriage, as to make its working worth the consideration of the Government of India, or the speculation of a private company. Poor Voysey! who travelled through this country from Nagpore eastward to Calcutta, through Sumbulpore, and met with black slaty limestone, black calcareous clay slate and sandstone on his way thither, states of them at Lowan and Bellagurh :—"I am convinced that the rocks of this formation are contemporaneous with, and [or ?] prior to, the granite." But he did not live to communicate more about them, for he died (of the fever mentioned in his Journal) between the left bank of the Subunreeka and Calcutta, having been found in his palanquin 24 hours after death.

For an analysis of this coal I must refer the reader to the table on this subject published in vol. vii. of the Bl. As. Journ. p. 197, which was extracted from one of the reports of the Coal Committee. To this I have only to add, that the coal occasionally presents the spheroidal structure common to many formations. The so-called "Ball-coal" sent by Mr. Williams from the Burdwan mines to Mr. Piddington is of this kind, the spheroids of which are from the size of a "cannon-ball to a man's head;" some are 18 inches in diameter. Mr. Piddington states that the apparently concentric layers are oblique "rhomboidal prisms."

The vegetable impressions from the "Sandstone and Clay, with beds of coal," in Cutch, are described by Mr. J. Morris, at the end of Captain Grant's Geology of that province. (See descriptions of these *antè*, pp. 444 to 446.)

To the "Report of the Geological Survey of India for the Season 1848-49," Dr. M'Clelland has appended the following descriptions of vegetable impressions found in the Burdwan Coal-field :—

"*Burdwan Fossils.*"

"I may here add in this place the following undescribed fossils of the Burdwan coal-field, which may serve as a term of comparison between the Burdwan and other coal-fields generally; most of them are in the collection of the Asiatic Society.

"*Zamia Burdwanensis.*—Leaflets linear-oblong, broadly inserted at the base, and rounded at the apex.

"*Sphœnophyllum speciosa.*—*Trizygia speciosa*, Royle's Illust. 2. fig. 8.—Leaves verticillate, fan-shaped, frequently bi-lobed ; placed in threes at intervals on a slender floating stem.

"*Obs.* There can be no doubt of this being a well-marked *Sphœnophyllum*, having the furrowed stem and bifurcated venation of that genus.

"It is the most beautiful fossil hitherto found in the Burdwan coal measures.

"*Sphœnophyllum fasciculatum.*—Leaves verticillate, fan-shaped, in dense imbricated fasciculi, probably at intervals, on a slender floating stem. Discovered by Mr. Theobald in the Burdwan coal formation.

"This fossil occurs in the form of detached lenticular bodies, from half an inch to an inch in diameter, and is so abundant as to give quite a character to some of the upper beds of bituminous shale of the coal formation.

"*Obs.* From the shape and detached character of these bodies, they might be supposed to be the strobili of some coniferous plant, and being composed of an infinity of densely imbricated scales, may still prove to be of that nature. But the fine leafy and membranous character of the scales, presenting the venation of *Sphœnophyllum*, suggests the probability of their being dense whorls of leaves or fronds.

"*Poacites muricata.*—Leaf long and ensiform, upwards of an inch in breadth, and consisting of parallel unconnected veins.

"*Obs.* It occurs in the Burdwan coal-field, along with *Fucoides venosus.*

"*Poacites minor.*—This is an ensiform leaf, usually half an inch in breadth, and of indefinite length, consisting of seven or eight coarse, longitudinal, equal veins, without any transverse connection with each other.

"*Obs.* It is found in bituminous shale in the Rajmahal and Burdwan coal measures ; and also in arenaceous shale in the Burdwan coal-field.

"*Glossopteris acaulis.*—Spreading and stemless ; the fronds long, stipitate, linear-oblong, becoming irregularly narrow at the base ; apex broad, obtusely pointed ; primary veins bifurcate ; secondaries and tertiaries reticulate.

"*Variety.*—In which the primary veins are dichotomous, and the secondaries bifurcate.

"*Glossopteris frondosa.*—Fronds oblong ovate, midrib slender, and continued to the apex of the frond ; veins slender, diverging at an obtuse angle from the midrib ; all of an equal size, and reticulated.

"*Obs.* Only two incomplete fragments of the upper and middle portion of the frond have been examined, from which it would appear to be from 4 to 8 inches in length, and 1½ to 3 inches broad.

"*Glossopteris reticulata.*—Leaves oblong, ovate ; narrow at the base ; apex obtuse,

lanceolate ; midrib strong, gradually tapering, and terminating before it reaches the apex ; primary veins close-set and numerous, curved, and arising acutely from the midrib ; secondaries finely reticulated.

"*Tæniopteris danœoides—Glossopteris danœoides*, Royle, Illust. l. c.—Frond ovate ; veins bifurcate, parallel, without tertiary veins.

"*Obs.* Various specimens show the fronds of this fossil to have been from 3 to 5 inches in length, and from 1½ to 2½ in breadth.

"*Note.*—Calamites occur both in the Burdwan and Rajmahal coal measures, but I have seen no specimens of them in collections. One large species occurs in the sandstone of the coal measures at Kottyeoon, in the Rajmahal hills, of which, however, no specimens were collected.

"*Pecopteris Lindleyana*, Royle.—Bipinnate ; pinnæ given off nearly at right angles with the midrib, linear-oblong and oblong-ovate ; secondary pinnules having the vein in the centre of each pinnule nearly straight, and extending from the base to the apex of the pinnule, giving off obliquely six to ten small branches or tertiary veins on either side.

"*Variety.*—Secondary venule in the centre of each pinnule more curved, and acute at its origin ; probably a distinct species, but the specimens examined are too imperfect to allow of the satisfactory determination of this point.

"*Pecopteris affinis.*—Bipinnate, central vein of each pinnule bifurcate ; in other respects it is the same as *P. Lindleyana.*

"*Variety.*—Pinnules closely placed, so as to appear almost as the lobes of an incised leaflet.

"*Fucoides venosus.*—Frond simple, membrano-fleshy, hidden veined, spatulate, linear-oblong, base prolonged and narrow ; apex obtuse and rounded ; midrib broad at the base, gradually diminishing to the apex ; the venation, where it is perceptible, is acute with the midrib, and arched. This fossil is contained in bituminous shale of the Burdwan Coal-field.

"*Conclusion derived from the foregoing Fossils.*"

"*Obs.* Comparing the above results with the general distribution of fossil plants, we find four genera, namely, *Zamia*, *Tæniopteris*, *Fucoides*, and *Pecopteris*, afford twenty species of lower Oolite fossils, and eleven coal measure fossils. Of eight genera of Indian coal measure fossils here described, four of them are common to the coal measures of Europe, namely, *Sphœnophyllum*, *Poacites*, *Calamites*, and *Pecopteris.*"

To these may be added Royle's *Vertebraria Indica* and *V. radiata* from Burdwan, figured in pl. ii. of his "Illust. Bot. Himalaya" ; and Brongniart's *Glossopteris Browniana* and *G. Angustifolia*, from the Ranigunge mines, near Rajmahal.

Also the two Icthyolites found by Drs. Walker and Bell respectively, at Kotah, in the Nizam's territories, near the confluence of the Godavery and Pranheeta. That of the former, named by Colonel Sykes *Lepidotus Deccanensis*, in "bituminous schiste," is stated by Sir P. Egerton, who examined these organic remains, to be a new species. "The scales are perfectly smooth, and the free posterior margins entire, without any trace of serration. A ramus of the lower jaw is seen in one specimen, showing the teeth to be conical, with rather elongated bases. There is little doubt but that it is a true Oolitic form, and apparently of the date of the Lias." "The genus Lepidotus

was probably an estuary or in-shore fish, from its frequent association with terrestrial vegetable remains, as in the Hyderabad specimen." (See p. 301, *antè*, and Dr. Bell's paper, p. 303.)

The following is Dr. Bell's subsequent communication on the strata at Kotah, and Sir P. Egerton's descriptions of the two other Icthyolites which he found there.

Further Account of the Boring at Kotah Deccan; and a Notice of an Icthyolite from that place. By Dr. T. L. Bell, Surgeon 3rd Nizam's Cavalry. *Communicated by Colonel Sykes, F.R.S., F.G.S.*

[Abstract.]

In the August number of the Quarterly Journal of the Society for 1852 (vol. viii. p. 230 [see also *antè*, p. 303]), is an account of the boring lately made at Kotah in the Deccan, in search of coal; and at p. 272 [*antè*, p. 301] of the seventh volume of the Journal is an account of the fish (*Lepidotus Deccanensis*) from the bituminous shale met with in the boring. In the present communication Dr. Bell states that, on account of the washing in of the soil, it was found necessary to make a new bore. After taking precautionary measures, by constructing a wooden shaft through the alluvium, the boring was carried through the 27 feet of limestones, shales, &c., that were penetrated the previous year (1851), and a further depth of 64 feet 11 inches attained. This consisted of:—

	Ft.	in.
Limestone	23	0
Blue clay	7	6
Limestone	2	0
Shale and clay	1	9
Limestone (more compact and crystalline)	1	8
Blue clay and shale	12	0
Red clay, penetrated to the depth of	17	0

An Icthyolite having been found in a state of limestone from the loose mass by the river side, noticed in Dr. Bell's former paper (*loc. cit.*), and which Dr. Bell regards as having been forced up by the action of the river, it has been forwarded to England by General Fraser; and Colonel Sykes having submitted the specimen to Sir P. Egerton, he was favoured by Sir Phillip with the following opinion respecting the character and relations of the Indian fossil: "It belongs to the section of the genus *Dapedius with single-pointed teeth;—Tetragonolepis* of Agassiz—not of Bronn. It appears to be a new species, differing from those hitherto described, in the ornamental pattern of the scales. It is an Oolitic form, probably of the age of the Lias."

Colonel Sykes proposes to name the second Oolitic fish from the Deccan, *Dapedius Egertoni*. (Quart. Journ. Geol. Soc. vol. ix. p. 351.)

On Two New Species of Lepidotus from the Deccan. By Sir P. De M. Grey Egerton, Bart., M.P., F.R.S., F.G.S.

The discovery of the remains of fossil fish in the table-land of the Deccan was first brought under the notice of the Geological Society in 1851 by Colonel Sykes [*antè*, p. 301]. The only specimen he had then received sufficiently perfect for description proved to be a new species of the genus *Lepidotus*. In the course of last year [*vide suprà*] further specimens were received from the same district, but appa-

rently from a different bed, which indicated a new series of the genus *Tetragonolepis* of Agassiz, now *Æchnodus.*

The specimens described in this memoir were sent to me a few days since by Colonel Sykes. They are bedded in a similar bituminous shale to that containing *Lepidotus Deccanensis,* and are stated to have been found in the same locality. They are both clearly distinct from that species and from each other, although they all possess in common the characteristic of the Liassic section of the genus *Lepidotus.*

Lepidotus longiceps, Egerton.

There are two specimens assignable to this species; one much mutilated, the other very perfect, with the exception of the tail. The length of the latter fish is 9½ inches; of this the head occupies within a fraction of 3½ inches, or more than one-third. The greatest depth of the body is 3 inches. The form of the head is elongated, and the nostril portion is more acutely produced than is usual in this genus. The lower jaw is of equal length with the upper jaw, and they are both armed with similarly proportioned teeth, of a conical form; those in the anterior portion of the jaws being more elongated than the more remote ones.

The cranial and opercular bones are of considerable thickness, and are invested with a very compact enamelled casing. Small isolated granules of shining ganoine are irregularly scattered over their surface. The preoperculum differs from the other opercular plates in having a more rugged and uneven surface.

The bones constituting the thoracic arch are of considerable substance, more especially the coracoid bone, which is very strong and flattened out at its posterior margin. Immediately behind the humeral bones, two or three broad irregularly-shaped scales occur, coarsely notched on their hinder margins, and covered with an unusually thick coating of ganoine.

The pectoral fins are about 2 inches in length. The rays composing them are numerous, but not remarkably strong. The ventral fins are inserted about half-way between the pectoral and anal fins. The latter fin is situated near the tail. It is composed of ten rays, the anterior one being fringed with a set of oblique osselets along its border. The rays have frequent transverse articulations, and are much subdivided in the expanded portion of the fin.

The dorsal fin, as generally happens in this genus, occupies a remote position, commencing at a point behind the insertion of the ventral fins, and extending beyond the anterior rays of the anal fin. It contains twelve rays, corresponding very closely in form and dimensions with those of the anal fin. A similar bordure of fulcral osselets characterises the anterior ray. Nothing remains of the caudal fin, save two or three of the elongated scales, indicating the commencement of its superior lobe.

The scales are for the most part smaller and more rectangular than those of *Lepidotus Deccanensis.* The dorso-ventral series contain about twenty, the longitudinal series about thirty. On receding from the head they gradually lose their rectangular outline and become more and more rhomboidal. A few scales in the vicinity of the coracoid bone are considerably larger than those in any other region of the body. Where the outer surface of the scale is preserved, it is seen to be distinctly radiated, and pectinated on the posterior margin.

In general appearance this species, although belonging to the more elongated group of the genus, is not so slender as *Lepidotus pectinatus* or *Lepidotus Deccanensis.* Its

most striking feature is the unusually large proportion of the head to the total length. This peculiarity serves to distinguish it from all the species hitherto described, and has suggested the propriety of the specific appellation.

Lepidotus breviceps, Egerton.

The evidence of a second species of Lepidotus among the ichthyolites recently received by Colonel Sykes is pretty clear, although the specimens affording it are deficient in many details. One specimen and its counterpart contain a head and a small portion of the body; another specimen shows the impression of the trunk as far as the base of the tail, and its mutilated counterpart contains the base of the skull and the scales of the anterior and middle portion of the body. With the exception of a few scattered rays, all the fins are wanting.

The length of the fish from the nose to the base of the tail is 7 inches, the greatest depth being 2½ inches. The head measures 2¼ inches, or less than one-third of the entire length. It will be seen, on comparing these dimensions with those of other species of *Lepidotus*, that this is one of the smaller species of the genus.

In general form it very much resembles the American genus *Ischypterus;* and indeed in size it corresponds pretty nearly with the larger specimens of *Ischypterus fultus*. The muzzle is pointed, but not so acutely as that of the species last described; the maxillary and facial bones are shorter, but the opercular bones are proportionately larger. The form of the trunk is remarkable for the vaulted outline of the back, in front of the position of the dorsal fin. The opercular bones are more profusely ornamented than those of *Lepidotus longiceps*. Although a few similarly isolated granules occur here and there, these are associated with a surface ornamented of larger grains, which in some places become confluent. The preoperculum has, nevertheless, a more even surface than in that species. The maxillary bones are shorter, and the teeth less elongated. The frontal bones have a coarsely corrugated exterior, beset with pustuliform grains of larger size than those on the surface of the opercular bones. The coracoid bone is less flattened than in the former species. The scales are small in size, and are entirely devoid of pattern on their surface; nor have they any serrations on the posterior margin. In these respects they afford a good distinctive character from those of *Lepidotus longiceps*.

In addition to the specimens enumerated above, from the bituminous schist, the collection contains a fragment of a large *Lepidotus* apparently from a bed of compact argillaceous limestone, similar to that containing the specimen of *Æchnodus Egertoni* described last year.* This may possibly indicate another species.

It may be worthy of remark that the genus *Lepidotus* has the most extensive geographical range of any genus of fossil fish with which we are acquainted. It has representatives from England, several localities in France and Germany, from Switzerland, the Tyrol, Lombardy, Naples, Greece, the Brazils, and from Central India. Its stratigraphical range is also extensive, viz. from the Lias to the Calcaire Grossier, both inclusive.

Description of Plate XII.†

Fig. 1. Lepidotus longiceps, nat. size.
Fig. 2. Lepidotus brevieeps, nat. size.

* *Tetragonolepis Egerton*, Sikes; *vide suprá*.

† See Quart. Journal Geol. Soc. vol. x.

Note on the Fossils from Kotah, Deccan.

The ichthyolites above described were forwarded to Colonel Sykes by Dr. T. L. Bell in the summer of 1853; and in a letter, dated July 12th, 1853, Dr. Bell states that these specimens were taken from the same spot at Kotah, from which those previously sent were obtained.

The specimens of bituminous shale contain, besides the fish-remains, some coprolites and traces of plants. There are also four specimens of impure limestone with fish-remains (*Lepidotus* and *Æchnodus*).

Some small pieces of a reddish, friable coarse sandstone or grit, containing obscure traces of wood, accompany the above, and are mentioned as having been obtained about 200 yards further up the river, where this is the surface-rock, and rests upon limestone. The specimen sent of the latter is similar to the limestone with fish-remains above mentioned, and to that referred to in the former notices.

Dr. Bell also forwarded with the above several fragments of dark clay-slates, and of a black micaceous quartzy schist, with a coarsely-wrinkled surface and obscure vermiform markings. These specimens, he observes, "were collected fifteen miles NE. from Kotah, at the foot of a range of hills 400 feet high, whose general direction is parallel to the other hills at Kotah and in the surrounding country, but with an underlying stratum of clay-slate, which has a dip directly opposite to that of the underlying strata at Kotah. This clay-slate is very extensive. I traced it until it was lost beneath the sandstone range. The layers composing it are extremely fissile, and break up into rhomboidal masses soon after exposure. I observed, while tracing it, evidence of disturbance in the form of a fault in one case and a bend in another, separated from each other by about 800 yards." (Quart Jourl. Geol. Soc. vol. x. p. 371.)

Punna Sandstone. (H. J. C.)

This name is derived from the town of Punna, in Bundelkhund, above which is a range of hills called by Franklin the "Punna hills or Second Range," but which Jacquemont, as before stated, found to be a third range.

Synonyms.—Diamond Sandstone (Malcolmson). Upper part of Voysey's "Clay-slate Formation."

It is to be regretted that Jacquemont, who first pointed out the existence of this range, was not able to explore more than the lower part of it, which the following extract from his work will show is composed of sandstone resting on the Kattra Shales:—"Je ne suis pas monté sur leur sommet [the Punna hills]; leurs pentes sont couvertes de bois, que plusieurs espèces de Mimoses rendent d'un accès très pénible; mais je me suis élevé jusqu'à leur hauteur moyenne, dans le lit de quelques ruisseaux qui en descendent. Les fragments dont ils sont remplis sont une table abrégée des couches qui constitutent les assises supérieures. Or, je n'y trouve qu'une seule variété de Grés, plus rouge qu'aucune de celles que j'ai observé dans la première et la deuxième rangée, lie de vin clair, à grain très fin, compacte. Quelques-uns de ces Grés sont

mouchetés de blanc, et ressemblent grossièrement à des porphyres. Ces points blancs sont des parties ou l'oxyde de fer n'a pas pénétré." He then observes:—"Les seuls bancs de Grés que j'ai vus à découvert vers la base des collines, offraient la structure concentrique que j'ai remarqué dans les couches de la base de la première rangée en montant de Mirzapoor à Lalgandje, mais avec cette différence, que leurs surfaces étaient plutôt planes que courbes. Ce sont des sortes de parallélipipèdes emboités les uns dans les autres." I have added the latter observation because it coincides with a similar structure noticed by Captain Sherwill "at the foot of the hill of Sasseram, in the zillah of Shahabad, which forms the termination of a spur thrown off from the northern face of the lofty range of the Keymore sandstone mountains." This is at the eastern extremity of the sandstone tract of Bundlekhund, which we shall also find by-and-bye to be composed of nothing but the Punna Sandstone, resting on the Kattra Shales with their limestone cropping out at Rhotasghur and other places close by. The structure is so remarkable, that it has received a particular description by Captain Sherwill, who, like Jacquemont, first terms it "concentric," and then observes, that the pressure above and laterally has caused them [the spheres, which are in rows] to be so much flattened that they resemble square columns."

To return, however, to the plateau of Bundelkhund. We find that Franklin, in describing the escarpments of four waterfalls, ranging from 272 to 400 feet deep, all along the same declivity, and within forty miles of each other, states, that they are all composed of the same sandstone formation; and in one instance, that it rests on argillaceous strata. The latter fact establishes the identity between it and the Punna Sandstone. Moreover, the easternmost waterfall is not more than thirty miles from the banks of the Son, which banks we shall by-and-bye find to be composed almost entirely of the Punna Sandstone, resting, as before stated, on the Kattra Shales. Fortunately Franklin has been particular in his description of this sandstone at each of the waterfalls, and therefore, from his and Jacquemont's observations, we shall be able to take our description of it from Bundelkhund, assisted by the remarks of others who have incidentally alluded to it, in this part of India.

Mineralogical and Geological Characters.—From these sources, and the specimens I have seen of this sandstone, it appears to be composed of very fine grains of quartz, and more or less mica, united together by an argillaceous material. The latter varies in quantity, and the mica may be entirely absent. It seems generally to be of fine structure, and coloured with different tints of red, brown, lilac, grey, and white, or any two of these together, the one forming streaks, spots, or specks, in a ground of the other. Superiorly it appears to be compact

and quartzy, becoming more friable and loose below. It has been horizontally deposited, and now presents massive and lamellar strata.

To these characters it appears necessary to add, that its texture may become so coarse as to pass into a conglomerate; at the same time that it is also necessary to caution the observer against confounding this conglomerate with one, apparently of subsequent formation, which may overlie this sandstone, and which will be hereafter mentioned.

The Punna Sandstone rests conformably on the Kattra Shales, which appear to pass into it, in the same manner as the Tara Sandstone passes into the latter (foot-note, p. 654); Newbold, however, uses the words, "frequent conformability" with reference to the stratification of these two divisions (Journ. Roy. As. Soc. vol. viii. p. 157); in some parts of Southern India it rests directly on the limestone, without the intervention of any shales (Malcolmson), and in others, alternates with it (Newbold, *loc. cit.*).

Its thickness varies, either from original inequality or subsequent denudation. At present its greatest known depth is in the eastern part of the Keymore range, which is but a continuation eastwardly of the Vindhya range, and the north-eastern part of the sandstone tract of Bundelkhund. Here it is 700 feet thick, near Bidjighur on the banks of the Son (Osborne), and 1,300 feet thick at Rhotasghur, in the zillah of Shahabad (Sherwill); at the scarps of the waterfalls in Bundelkhund, which were examined by Franklin, it does not appear to exceed 360 or 400 feet, and Jacquemont considered the Punna range of hills to be about 300 feet above the level of the second plateau. From 300 to 400 feet is the thickness given to it in south-western India, about Ryelcherro and Sundrogam, in the Ceded Districts (Newbold). On the opposite side, however, viz. at Paloonchati, about fifteen miles west of the Godavery, and in nearly 18° N., there is a range of entire sandstone hills, which appear to rest on argillaceous strata, that Voysey considered 600 feet high, but which Mr. Burr, who was then surveying these districts, thought 1,200 feet high. The falls of Gokak present a sandstone escarpment of only 178 feet high, with aluminous shales of various colours at the base (Newbold). In many places this sandstone is not only much thinner than this, but altogether absent, when the limestone or argillaceous strata of the shales becomes the highest member of the series, as in the vicinity of the Bhima, in the district of Shorapore, &c.

It attains its greatest height on the banks of the Kistnah, viz. 3,000 feet (Malcolmson), while in the plains of the Carnatic, and the districts watered by the Pennaar river, it is but a little above the level of the sea (*id.*).

Frequently its upper part is in the state of quartz rock, presenting great fissures; occasionally also, in Southern India, it has a jointed

rhomboidal structure (Malcolmson), and sometimes the concentric lamellar one. Christie and Newbold mention this in the Southern Mahratta Country, and the latter also at the Gundicotta pass; to its existence at Sasseram and in Bundelkhund I have already alluded. It is also sometimes brecciated from volcanic disturbance and subsequent reconsolidation.

The hills or mountains capped with this sandstone and the shales, generally, present a scarp of the former, followed by an inclined plane of the latter, while the summit is either horizontal, or terminated by a rugged fantastic outline, not unlike old ruins.

Subject as this series has been throughout to the intrusion of igneous rocks, and the violent displacement which accompanies subterranean force, the Punna Sandstone has of course participated in the general overthrow, and appears in all kinds of positions and conditions; but no one mentions the intrusion into it of anything but dikes of the trappean rocks. Malcolmson states that a few miles north of Nagpore the strata of "red sandstone are bent, fractured, and converted into compact quartz rock, at their point of contact with the granite, which has burst through it"; but I am not quite sure if this be the sandstone under consideration.

When metamorphosed into quartz rock, it would appear to have been sometimes called "hornstone." Tod, I think, calls it "trap"! in alluding to the formation of the plateau of Kotah in Mewar. He observes that this plateau consists of "trap," the prevailing colour of which is white; it is of a compact and close-grained structure, of a white colour; and, about Kolali, porphyritic; at Shahadabad, it is of a mixed red and brown colour, and when decomposed would be taken for a "gritstone." Dangerfield sets it down in his geological map of Malwa as "hornstone porphyry," the same as the ridge bounding the trap of Malwa close by, which rests on the shales; and Hardie gives a similar description of the capping of the hill of Chittore, which Tod includes in the district or plateau of Kotah. Hardie, however, calls this "quartzose breccia," and states that it presents scarped sides, which terminate in a sloping plane of the shales on which it rests. We can hardly, I think, fail to recognise in this the Punna Sandstone. Sherwill, again, in his description of the Rajghur Hills, of the Zillah Bahar, calls the latter "hornstone," and adds that they present lively colours of red, purple, blue, greyish-green, &c. Newbold mentions a similar rock in the eastern Ghàts west of Nellore, and considers it to be altered sandstone. The quartz hills of Ajmeer, of a violet or purplish tint, and indeed all those alluded to by Tod, appear to be the Punna Sandstone metamorphosed, although I have placed them among the older metamorphic rocks, but this is only done provisionally.

Geographical Extension.—The Punna Sandstone appears to be almost unlimited in its extent over the tract upon which we are engaged. It appears to be present at Nahn in the Sub-Himalayan range between the tributaries of the Jumna and Sutlej, and to extend as far south as the Nagerry hills, in the eastern Ghàts WNW. of Madras, to Cutch in the west, and to the Rajmahal hills in the east. Grant states that the hills about Bhooj "assume, when capped by the sandstone, the usual form of an abrupt escarpment, with a long inclined opposite side." All the towns on the Jumna, from its confluence with the Ganges to Delhi, appear to be built of this sandstone, and among their edifices stands forth the Taj Mahal, edged with the beautiful white metamorphosed limestone of this (?) series.

The plains of Bikaneer, Jodpore, and Jessulmeer, appear to be covered with the loose sand of this formation, which every now and then projects above these dreary wastes in its concrete or metamorphosed forms. Our museum possesses specimens from Balmeer presented by Dr. F. Forbes ;—from Cutch, and from Kattywar. It borders the northern and western sides of the trappean tract of Malwa (Dangerfield), and appears in the Bundair hills of Bundelkhund, on its eastern side, extending to the utmost limits of the Vindhya range, which in this direction may be said to reach Monghyr, on the Ganges. Westwards to Hoshungabad ; and on the opposite side of the Nerbudda, forming the north-eastern boundary of the great trappean tract of Western India, from which we have numerous specimens from Dr. Bradley ; appearing at Nagpore, and extending from thence along the Godavery to its debouchment. In the Southern Mahratta Country, on the Bhima, along the Kistnah, and more or less continuously on the eastern side of the peninsula from this river to the Nagerry Hills, beyond which its existence has not been recognised, nor does it appear to have been seen on the western side from the Ceded Districts to Cape Comorin.

Minerals.—If the quartz mountains of Ajmeer be this sandstone metamorphosed, then it contains lead and copper, as has before been stated ; and when we remember that the limestone about Cuddapah, which is intimately connected with this sandstone, contains galena in several places, it does not seem very improbable. Further than this I know of no other mineral worth working in it. In the introduction, it is stated that the Oolitic Series yields iron ore, but as yet I think there is no satisfactory evidence of its existence in it to any great extent, at all events in the unmetamorphosed condition of the strata. The resources of this series appear to be more economical than mineral ; at the commencement of the group I have, by mistake, used the latter word, which is, perhaps, more applicable to the Older Metamorphic Strata. In what "clay-slate" is the copper of Nellore, &c. ?

Organic Remains.—For many years past the sandstone of India has been known to yield impressions of plants. Captain Dangerfield, in his letter to Sir John Malcolm on the geological features of Malwa, written more than thirty years since, states that he saw between the slaty fracture of the sandstone at Jeerun, in Malwa, passing northward to Odeypore, "numerous vegetable remains or impressions of a species of fern, appearing to be in a carbonized state," and we know now sufficient to reasonably infer that this is the sandstone under consideration.

Grant, about 1837, found the impressions above described in the "sandstone and clay with beds of coal" in Cutch. We have only one specimen of the Cutch sandstone bearing a vegetable impression in the museum, and that very closely resembles the fine micaceous sandstone at the North of Ellichpoor, and that in the neighbourhood of Nagpore, which also bears vegetable impressions.

But it is only within the last year that our attention has been forcibly drawn to the organic remains of this member of the Oolitic Series. The happy coincidence of a favourable locality and able inquirers has furnished us with a list of fossils that will establish a lasting interest in the organic remains of this sandstone, and soon set at rest all discussions respecting the geological age of the series to which it belongs. I allude to the researches of the Rev. Messrs. Hislop and Hunter, whose "Geology of the Nagpur State" is published in the last number of our Journal (Bomb. As. Soc. vol. v.), and from which the following descriptions of the fossils in the sandstone of Nagpore are extracted :—

"*Mollusca.**—These occur only at Mángali, sixty miles south of Nagpur, and consist of two species of minute *Cyrena* (?), one, which is the smaller, being globular, and the other flatter and more elongated.

"The vegetable remains are exceedingly abundant, and are to be found in all places where the middle beds appear. They have also been recently discovered in a similar position near Elichpur, by Dr. Bradley. As they are met with at Nagpur and the surrounding country, they include seeds, leaves, and stems.

"*Seeds.*—Four species. Of these the first two discovered were found at Bhokára. Notwithstanding their being smaller, they are evidently related to two of the forms of *Carpolithes* figured by Lindley and Hutton in their *Fossil Flora*, vol. iii. p. 193. The third kind of seed was first met with at Kámpti, by Mr. Sankey; to whom I am under many obligations for this as well as other favours. Shortly after Captain Wapshare and I found it at Tondakheiri, fourteen miles

* "From an ingenious suggestion made by Drs. Leith and Carter, I was led to believe that the bivalves referred to, belong to the *Entomostraca*, and I am informed by T. R. Jones, Esq., that they are to be assigned to the genus *Estheria.*"—S. H.

NW. of Nagpur. A fourth seed, which occurs at Silewádá, is lanceolate, and very minute. Under this head may, perhaps, require to be comprehended a circular depression, resembling in size and form the impression left on wax by a pretty large key, which was discovered by Captain Wapshare at Bhokára.

" *Leaves.—Dicotyledonous* 2. One, a leaf of a conifer, about 1 inch long and ⅕ inch broad across the middle, midrib included. It has obviously been a strong inflexible leaf, and with its sharp point may have been rather formidable. A small piece of *Zamites* from Kámpti, not ½ inch long, and yet it gives off from its tiny midrib twenty pinnules, each containing six or seven microscopic veins. There are several leaves observable in the strata at Kámpti, apparently *Monocotyledonous*. One, kindly contributed by Mr. Sankey, is 17 inches long and ¾ inch broad. Before deposition it had been split in two for about two-thirds of its length. It may possibly be the leaflet of a large *Zamites;* but I am disposed to consider it rather a *Poacites*, with very minute venation. The same may be said of another curious object, which has left forty-two parallel lines,* stretching across a confused mass of vegetation, for a distance of 3 inches, and with a breadth of ¾ of an inch.

" But the most common and beautiful leaves which the sandstone formation produces are the fronds of ferns. They include—

" *Pecopteris.*—Of this genus but few specimens have been found, and these at Kámpti only. They are, however, of two distinct species. A pinna belonging to one of these species is furnished on each side with eleven pinnules, with a central vein, reaching to the apex. A specimen of the other species is very perfect, and presents four bipinnate fragments, lying together in such a manner as to indicate a tripinnate frond, pinnæ with from eight to ten pinnules on each side, the venation much branched, and without a central vein extending to the apex.

" *Glossopteris.*—The species of this genus are very numerous, amounting to ten, and all in excellent preservation. With their large iron-coloured fronds and distinct veins, and in several instances with their perfect fructification, they form the most interesting fossils of the vegetable kingdom that I have ever seen. The species differ from each other in size, shape, venation, and arrangement of the sori. One of them is upwards of 20 inches long and 3 broad, while some slabs are entirely covered with a species little more than 3 inches in length. Some have the venation coarse, others fine; some have it starting from the midrib at a very acute angle, others nearly at right angles. The sori in all cases are dot-like; but in some they are large and round; in others they are small and elongated; in some they are

* " These parallel lines I afterwards found to be the veins of a large *Tæniopteris* agreeing in a remarkable manner with *Tæniopteris magnifolia* of the Virginian Oolitic Coal-field."—S. H.

placed chiefly along the margin, in others with four or five rows they fill up almost the whole of the frond. This genus is the most widely diffused of any in the formation within the Nagpur State. It has been found at Chándá, and also at Chorkheiri, a distance of one hundred and twenty miles, and at intermediate places. The locality that has furnished most species is Silewádá, whence I was favoured with a magnificent slab by Captain Wapshare.

" *Cyclopteris.*—One species of this genus has been discovered at Tondakheiri, along with the coniferous leaf; length 2½ inches, breadth 1 inch. The frond is crowned with fructification in form like the flower of a cultivated cockscomb. Another species met with at Kámpti is much larger.

" *Sphenopteris.*—The specimens of this genus which are imbedded along with those of *Pecopteris* are much mutilated; but the small fragments that are found exhibit a very elaborate, though clear, venation.

" *Tæniopteris.*—Two species, one narrow, with secondary veins straight and perpendicular to the median; the other very broad, with secondary veins curved and oblique.

" *Stems.*—These are very abundant at Silewádá, including genera of which I can find no traces in any *Fossil Flora* to which I have had access. They are apparently *Exogenous*, but do not preserve the structure of the wood. They have possessed a well-defined bark, which is often obliquely striated, and exhibits the cicatrices of leaves, with a bud occasionally left after the foot-stalk had fallen off. Some of the scars are longitudinal; others are transverse, and embrace a considerable part of the stem. They are in general sparsely distributed, in one large stem 3 feet long, and upwards of a foot broad, there being only a single scar apparent. Besides these *Exogenous* stems, of which there are four or five different genera, there was one discovered at Mángali, along with *Cyrenæ* [Estheriæ], which can be distinctly referred to the conifers, from the lattice-like disposition of its scars. The wood of a coniferous stem converted into silex, but retaining no traces of its bark, was dug out from the road near Chándá. Other stems, preserving the wood, but so altered by iron that the structure cannot be determined further than that it must have been *Exogenous*, occur in abundance at Silewáda. On the other hand a stem imbedded in the rock at Mángali exhibits every mark of having been *Endogenous*. The portion obtained is like a thin rattan, 14 inches long, without any apparent joint. Under this sub-kingdom must also be classed—

" *Equisetites*, or, according to Bunbury, *Asterophyllites.*—The peculiarity of the specimen of this genus, which was discovered by Mr. Hunter at Silewádá, as well as of a Yorkshire one, figured in the *Fossil Flora* (vol. iii. p. 186) under the name of *Equisetum laterale*, is that it

is always found associated with little round discs, having 'lines radiating from a common centre, something like the phragma of a calamite.' The authors of the *Fossil Flora* were uncertain whether the discs belonged to the stem, near which they are found; but in the Silewádá specimen, the round bodies, of which there must have been two, and two opposite each other at the articulation, partly retain their original position, and partly have fallen out, leaving a radiating hollow to show where they once had been. A very common plant at the deposition of the sandstone was the—

"*Phyllotheca.*—In giving this name to the genus that has hitherto been called *Calamites* in India, I follow the high authority of Brongniart and McCoy, who have described specimens from Australia. The opposite sulcation of our Indian genus clearly separates it from *Calamites.* What place it ought to hold in a classification remains doubtful. Göppert ranks it among Monocotyledons, immediately after *Equisetites*, while McCoy compares it with the *Casuarina.* I have not been able, in the numerous specimens which I have met with, to verify the opinion of the latter eminent geologist, not having detected either bark or a phanerogamous fructification. There appear to be in all nine species collected from Bhokára, Silewádá, and Kámpti, differing in the number of *sulci*, which range from six in the semi-circumference to thirty-one. Two from Kámpti were sent to me by Mr. Sankey, and one from Silewádá by Captain Wapshare.

"*Vertebraria.*—This is the strangest genus among our Nagpur fossil plants. Hitherto it has been described from specimens obtained exclusively from the Indian and Australian coal-shale. This has led to a limited view of its nature. McCoy's generic character applies merely to the radiated body, which is found in connection with the main stem, and which he believes to be made up of a 'slender stem surrounded by densely aggregated whorls of verticillate cuneiform leaves, having a dichotomous venation.' Of the correctness of this description of what was before the author at the time, I have no reason to doubt, but it is quite inappropriate, when it comes to be predicated of the sandstone specimens. These have no slender stem or densely aggregated whorls of leaves. On the contrary, the main stem is thick, marked with two rows of oblong, rounded, or angular elevations and depressions, and giving off branches and twigs at different intervals, and in all directions. Mr. Sankey forwarded to me the first sandstone specimen from Kámpti, and in the same week I found it at Tondakheiri, and more recently at Chándá.

"Such are the principal fossils of the Sandstone, properly so called. Beneath it occur some beds of shale, which may be held as part of the same formation. These strata are developed in the district north of

Chándá, and between Korhádi and Bhokára, where the red shale contains the following organic remains:—

"*Reptilia?*—A footmark, of ⅓ of an inch long, and as much broad, with the impression of five (?) claws. Three specimens have been obtained, each exhibiting only one print. The shale, which is very brittle, does not admit of a surface of more than a few square inches being procured. On the same specimens as bear the footmarks are seen the tracks of—

"*Lumbricariæ* (Earthworms).—That these animals have been of the nature here indicated will be evident to any one who considers the appearance of the furrows: the way in which the head has occasionally been pushed forward, and then withdrawn; the tubular holes by which the ground has been pierced, and the intestine-shaped evacuations which have been left on the surface. Worm-borings have been found in the green shale of Ta*d*ádi, seventy miles south of Nagpur.

"The only vegetable organism, which has been discovered in the shale is a sulcated plant, which most probably belongs to the genus *Phyllotheca*, but, as a sufficient length of the stem has not been obtained to display the articulation, its precise character cannot be fixed."

Dr. Spilsbury sent to the Bengal Asiatic Society a specimen of silicified wood, which Captain Ousely obtained from a trunk of a tree that he observed passing through a cavern in this sandstone, near Pugra, on the left bank of the Nerbudda, on the road from Tendukira to Baitool. Do the "silicified palm trees" which Dr. Spry describes as resting on *limestone* about a mile from Saugur, belong to this formation, or to the thin intertrappean lacustrine one, to which we shall come by-and-bye? The Rev. Mr. Hislop states in his paper, that silicified wood abounds at Silewá*d*á; and Malcolmson observes that Mr. Geddes found it strewed over the country NW. of Mangapett on the Godavery, towards the junction of the latter with the Wurda (Pranheeta?), which is in this Sandstone Formation; while Malcolmson himself found "coniferous" wood at Mangapett, resembling that of Pondicherry. But the latter may also have come from the lacustrine formation to which I have just alluded (see foot-note, p. 658).

Newbold saw ripple marks in this sandstone at the falls of Gokak, and at the pass of Gundicotta.*

* Bearing on the foregoing formations is the result of the researches of the Geological Survey of India on a "considerable portion" of the Vindhya Range between the river Soane and Mundlaiser on the Nerbudda which took place during last year, and was made known by Mr. Oldham to the Asiatic Society of Bengal in May last (see their Journal, vol. xxv. p. 249).

Mr. Oldham observed that a series of sandstones of great thickness in which no organic remains had been found, but "in one or two places seemed to pass upwards conformably into

Minute Coralline Limestone of Baugh.

There is a fossiliferous limestone, of which much of the ornamental architecture in the once famous city of Mandoo, situated in the Vindhya range, about one hundred and sixty miles up the Nerbudda, is eonstrueted, and which differs from any other in India that I have seen described. Specimens of this limestone were presented to the Society by the late Lieutenant Blake, among other many valuable contributions of the kind whieh this officer made to the museum.

It is of two colours, red and yellow, mixed with white, and of a coarse, compact structure. This coarseness, when examined with a

sandstones holding remains of large mammalia (probably of Sewalek date)" composed the lofty and boldly scarped range of the Puchmurry or Mahadewa Hills; and that these in parts had been overflowed by the basaltic effusions of the Deccan; that this series rested "unconformably" on another formation consisting of "sandstones, shales, and coals," exceeding in this district "some thousand feet," and bearing impressions of plants which "thoroughly identified them" with the coal-groups of Burdwan, Hazareebagh, and Cuttack; and that these again rested "unconformably" upon a great group of a more ancient epoch and altogether different in character, in which no fossils had been found ("It might be Cambrian").

After adding that "the detailed examination of the greater part of the Nerbudda district was due to the exertions of Mr. J. G. Medlicott," Mr. Oldam observes :—

"The following would therefore give a summary view of the groups here proposed in descending order, neglecting for the present all the more recent divisions.

	Groups.	*Mineral Character.*	*Age, &c.*
	Mahadewa	Sandstones, with a few shaly beds, for the most part pebbly, often striped with ferruginous bands.	Geological age unknown, a few vegetable fossil stems, &c.
	Damoodah	Shales, sandstones, coal, for the most part thinly bedded and regular, often greatly cut up by trap dikes. *In Cuttack, however, there are no trap rocks.*	Age not thoroughly decided, probably Jurassic, fossils chiefly vegetable—name taken from the locality where series is most fully developed.
Vindhya.	Bundair	Sandstones, and shales.	Age unknown, probably very ancient, seen all along Vindhya range, into Behar and to the Ganges at Monghyr. Probably also in the Khasia Hills. Possibly only *two* subdivisions.
Vindhya.	Rewah	Limestones, shales and sandstone.	
Vindhya.	Kymore	Sandstones and limestones and shales.	
	Sub-Kymore ...... (name proposed by H. B. Medlicott, Esq.)......	Crystalline limestone pseudo-gneiss, micaceous schists, and quartzites, red and green, and white.	Highly probable, though not yet thoroughly proved, that these are only the continuation downwards of the Vindhya groups subsequently altered.

"Granite, gneiss, hornblende-rock, greenstone, &c.

"Another district of considerable interest had also been examined during the past season, by

Coddington lens, in a polished section, is found to depend on the presence of innumerable microscopic corals; and the colour, on oxide of iron, which is diffused through two-thirds of the mass. Many of the corals are branched, and their cellular arrangement varies with the species; of which there are several. The most prevalent appears to be one in which the cells radiate upwards and outwards in a curved form, from the longitudinal axis, in the manner of *Favosites*. The points most worthy of mention in the organic remains of this limestone, are the apparent absence of foraminifera, and, with the exception of a minute turbinated shell here and there, its almost entire composition of branches of minute corals, few of which exceed $\frac{1}{12}$ of an inch in diameter.

Jacquemont, who visited Mandoo, has also noticed this rock, and states that he could not find out the quarries from which it came; but the following passage from Captain Dangerfield's geological description will, I think, supply the deficiency:—

"Passing from Malwa to Guzerat, to the SW., the first well-marked descent occurs near Tirrella, and continues gradually for fourteen miles to Para. In the greater part of this distance occur the trap rocks of

Messrs. Blandford and Theobald, and the results arrived at under their careful scrutiny had been strongly confirmatory of the results given above. The Cuttack, or Talchere Coal-field gave the following section, descending:—

"*Alluvium, Laterite, &c.*"

"1.—Upper grit series,—unfossiliferous—quartzose grits and coarse sandstones, with occasional red shales; pebbly throughout, and near base conglomeratic—above 2,000 feet.

"2.—Carbonaceous shale series, fossiliferous, consisting of—

"Blue and lilac shales, micaceous; white speckled sandstones and ironstones, about 1,500 feet thick.

"Carbonaceous shales containing thin seams of coal (3 inches) irregularly dispersed through them, about 200 feet.

"Shales and coarse white sandstones, the latter predominate in lower portion, 100 to 200 feet.

"3.—Lower shale and sandstone series, annelide tracks, consisting of—

"Blue nodular shales, generally arenaceous.

"Fine sandstones, much jointed and 'tesselated.'

"'Boulder bed,' containing numerous boulders of gneiss and granite frequently 5 to 6 feet across—in a fine argillaceous or arenaceous rock, often rippled, sometimes replaced by a coarse sandstone.

"Each of these series rested unconformably on that beneath it."

On the above observations I can make no remark further than that they carry with them the value of ocular evidence; but, as Mr. Oldham states, much remains "to be done in working out the details" upon which his "conclusions" are founded, and among these it will be satisfactory to see the corroborative testimony of others who have laboured in the same geological field.

Malwa, succeeded by coarse sandstones and limestones, with immense quartz beds, siliceous grit-stone, and coarse conglomerates. The lime-stone is in general coarse, approaching in parts to earthy, of a deep brick-red, intermixed with white, and containing often much silex."

This limestone, which is identical in description with that of Mandoo, has a very limited extent in his geological map, where he designates it "coarse granular," and seems to exist in two small strips on the sandstone close to Baugh, and to the same extent on the fine or compact limestone near Sadree. The former is about thirty-two miles west of Mandoo, and the latter about thirty miles west of Neemuch.

It is at Baugh, then, that the quarries of this limestone appear to exist, and as it seems more connected with the Oolitic Series than any other formation, I place its description here for the present, merely adding that I think it deserving of further examination, on account of its peculiarities, and the probability of its yielding fossils which might determine its geological age.

Diamond Conglomerate.

Connected with the Oolitic Series would appear to be the conglomerate which contains the diamonds of India, usually called the "Diamond Breccia," but why it should have been termed breccia, I am at a loss to conceive. Franklin and Newbold comment on this, and both would call it a conglomerate. Heyne also calls it a "conglomerate."

A breccia is formed by a subterranean succession or shock, which reduces more or less of the formation over which its influence extends to a fragmentary state, and these fragments are either retained *in situ*, and reconsolidated by a crystalline cement derived from the parent rock, or only carried to short distances, before they are united together by some foreign material. The fragments of a breccia are therefore necessarily *angular*, and this is its characteristic feature.

A conglomerate, on the other hand, is composed of such fragments after they have been rolled for some distance, or of the harder portions of disintegrated rocks, which have undergone similar transportation, and therefore have become more or less *round:* this is the charac-teristic feature of a conglomerate.

There is, therefore, a wide difference between the history of an angular portion of a rock, and that of a round one or pebble: the former can never have quitted far the rock to which it originally belonged; the latter may have travelled hundreds of miles. Thus it may fall from its parent rock into the bed of a river, be rolled and rounded in its passage thence to the sea: there it may undergo a further attrition, and be buried in some beach. After a lapse of time, by the changes of level in the

land, it may be situated in the middle of a continent, and the stratum in which it was last deposited having been fractured and raised above the common level of the country, it may again fall into another river; and, so on, may be transported from place to plaee for ages, or so long as its integrity exists.

Henec it also follows, that during the migration of the pebble, it may be thrown into eompany with others from various formations besides its own, all of which may be widely separated, and once or more in its travels it may be imbedded with the angular fragments of a rock whieh has been shattered elose to the plaee of its last deposit.

This appears to be the nature of the Diamond Conglomerate of India, whieh contains pebbles of quartz, jasper, lydian stone, epidote, mieaceous iron ore, garnets, eorundum, &c., varying aecording to the locality, mixed with semi-rounded and angular fragments of sandstone and shale, imbedded in quartz sand which has become more or less eonsolidated; the former being the hardest parts probably of the Older Metamorphie Strata and Plutonie Rocks, whieh must have been brought from a great distanee, or have undergone long attrition in some way or other to have attained their present roundness; and the latter, probably *débris* of the Oolitie Series, which, from their subangular and fragmental forms, indicate a much nearer origin. In the midst of this heterogeneous deposit, to which the term of eonglomerate is eertainly more applieable than breecia, the diamonds are seattered, and the whole spread over a great part of India in the way whieh will hereafter be mentioned.

The table at page 688 will afford the best seetions of the deposits in eompany with this eonglomerate that have been published. They have been eompiled from Voysey's deseription of the diamond mines at Banaganpilly, a village in Southern India, about twelve miles west of Nundiala, and about thirty S. by E. of Kurnool; and from Franklin and Jacquemont's deseriptions of the diamond mines at Punna, in Bundelkhund, both of whieh would appear to have been taken very earefully.

From these sections it will be observed, that there is a distinet series of deposits overlying the Punna Sandstone. Franklin states that the rocky matrix of the diamond rests on 400 feet of Sandstone, beneath which there are "strong indieations of eoal," and that the roeky matrix is superposed by 12 feet of argillaeeous shale, calcareous slates with dendritie markings and sandstone. Jaequemont eonfirms the latter part, with the exception of the "ealcareous slates, &c."; but gives a minute description of the composition of the strata, in whieh he states that there are *angular pieces of sandstone and shale* among the rounded pebbles of the diamound conglomerate.

Sections from the Surface to the Diamond Conglomerate inclusively.

BANAGANPILLY (Voysey).	Feet.	PUNNA (Franklin).	Feet.	PUNNA (Jacquemont).	Millim.
		Soil .... Red gravel .... }	2	Blocks of neighbouring sandstone. Soil. Red gravel. Blocks of neighbouring sandstone, and portions of red, blue, and green shales, in red argil	0-3
Sandstone, clay state, and slaty limestone ...	50	Shale, argillaceous; calcareous slates and sandstone of red, blue, and green colours, interlaminated....	12	Shale, red, green, and blue...... Shale, dreen, speckleg lilac...... Shale, red, green, and blue...... }	3-5
				Fin.-grained sandstone of a green colour	0-3
Pebbles.—Puddingstone; quartz; hornstone in argillo-calcareous, siliceous sand. Breccia.—Red and yellow jasper; quartz, calcedony and hornstone of various colours, in quartz sand; diamonds........	2	Pebbles.—Quartz, white and green; jasper; hornstone; lydian stone; portions of argillaceous schiste in white quartz; sand, sometimes ferruginous; diamonds.		Pebbles.—Red jasper; lydian stone; milk quartz; white angular fragments of green and ferruginous sandstone; hyaline quartz; semi-rounded portions of micaceous shale, red, white, and green, in adamantine green quartz sand; diamonds..............	0-3 to 1-6
		Compact sandstone	400		

In Southern India this little series would appear to be somewhat thicker, for Voysey states, that at one part he saw the "sandstone breccia" (diamond conglomerate) under 50 feet of "sandstone, clay slate, and slaty limestone"; while Dr. Heyne, according to Franklin, observes, that "the diamond bed is of the same nature with the rocks both above and below it; but is distinguished from them by its superior hardness, and that the floor is so hard that it strikes fire with steel," a peculiarity which Franklin states equally applies to the Punna Mines; and therefore the latter was of opinion that the diamond bed about Banaganpilly, to which Dr. Heyne referred, rested on sandstone. This, however, is not so evident as desirable.

But Newbold, in his description of the diamond mines of Banaganpilly, gives a section of the diamond conglomerate (which he states is interstratified with "highly crystalline ferruginous sandstone"), resting on dark blue limestone; and further states, in his Summary, that "fossil chert from the limestone is often found imbedded in the diamond breccias of Banaganpilly, &c." Also that "the pebbles from the limestone rocks are both rounded and angular," and that the diamond "conglomerate usually rests on limestone," in Southern India.

This is more conclusive with reference to its formation subsequent to the Oolitic Series than Dr. Heyne's observations, for two reasons, first, because it is more definite, and secondly, because it brings two deposits together of totally different natures, one of which, viz. the limestone, we now know must not only have been denuded, but broken up, before the other could have been formed.

It would appear, from the texture of the Punna Sandstone and the Kattra Shales, that for ages previous to the deposit of the diamond conglomerate, the currents of the water in which they were found must have been very light, and the material spread about by them very subtle; and, therefore, that both must have been suddenly changed when the diamond conglomerate began to be deposited, if not suspended altogether for a time, as the denudation of the limestone would seem to indicate.

The presence of angular portions of sandstone, and fragments of shales in the diamond conglomerate of Punna, with those of chert from the limestone at Banaganpilly, also supports this view.

All these observations tend to the conclusion that the diamond conglomerate is partly formed from the materials of, and therefore subsequently to the Oolitic Series, yet Voysey has stated that "the matrix of the diamond in Southern India is the sandstone breccia of the "clay slate formation," and his clay slate formation consists of the Punna Sandstone and Kattra Shales. It is possible that he may be right, but at the same time it is evident that the subject requires further investigation.

I should not omit to mention another diamond matrix which has been described by Franklin in Bundlekhund: it lies in crevices of the sandstone, or on the shales, and consists of a conglomerate of jasper, lydian, quartz, and more recent white sandstone pebbles, together with quartz sand, in a soft, plastic, yellow clay. In this are none of the green quartz pebbles, which indicate the presence of the best diamonds; and it is immediately covered by white quartz gravel, and then the red ferruginous gravel of the neighbourhood.

Among the pebbles from the metamorphic rocks in the diamond conglomerate of Southern India, Malcolmson mentions micaceous iron ore and corundum.

Lastly, in confirmation of the view above taken, of the existence of a conglomerate on the Punna Sandstone, and that conglomerate formed of *débris* of the Oolitic Series, would appear to be the following extract from the letter which Dr. Bell, of the Nizam's Service, kindly wrote me regarding the strata passed through in boring at Kotah. He states:—

"I observe in your section that you have omitted an important layer which exists in the Kotah district, namely the most superficial, which is a conglomerate: it is of no great thickness. Beneath this, we have sandstone, forming hills, varying from 50 to 500 feet in height, resting upon argillaceous limestone, 9 feet;" and then follows the list of the shales already mentioned. He afterwards adds:—"I mentioned the conglomerate bed as important, because in one of its water-worn fragments I discovered a crocodilian fossil, consisting of a mass of dermal scales, with a femur, and some fragments of other bones, upon which Professor Owen came to the conclusion that 'the character of the scales, as well as the length and slenderness of the femur, agree more with those of the *Teleosaurus* and amphicœlian crocodiles, than with the existing gavials.' This is a most significant fact, as it was picked up 520 feet above the level of the Pranheeta river."

Professor Owen's remarks by no means establish an identity between these crocodilian remains and those of the Oolitic period, though they tend to it. Dr. Bell, in a subsequent communication, informed me that they were found in a fragment of the conglomerate itself, and not in a water-worn fragment contained in the conglomerate.

There can, however, hardly be any doubt, that a conglomerate does exist on the sandstone of the Oolitic deposits, made up partly of their *débris*, whatever may be its age; and that, as this conglomerate is sometimes found resting on the limestone of the Kattra Shales, a considerable denudation must have occurred before this could have taken place; also that other rocks, which then presented a naked surface, might have this conglomerate resting on them as well as the members of the Oolitic Series.

Since writing the above, I have had an opportunity of reading Dr. Heyne's Tracts, who, in his excellent description of the diamond mines of Southern India, states that the diamond conglomerate caps the ranges of hills about Cuddapah, the highest of which is "about 1,000 feet above the level of the country"; that this capping is "between 10 and 20 feet thick"; and that "a similar stony cap" exists "in other parts of India, particularly about Chittledroog and Hurryhur," but that at these places "the hill and cap consist of different kinds of rock, whereas here [at Cuddapah] they are similar."

Of the nature of this capping Dr. H. observes :—"All the different places in which the diamond has been hitherto found consist either in alluvial soil, or in rocks of the latest formation, and containing such a great portion of rounded pebbles as to have rather the appearance of a conglomerate than any other species of stone."

In describing the diamond mines of Ovalumpilly, which are about six miles from Cuddapah, Dr. H. states:—"The surface soil is sandy, and 1 foot thick, after which comes 3 feet of red clay; and then the diamond conglomerate." "In the Ellore district the diamond stratum is covered by a thick stratum of calcareous trap." The thickness of the conglomerate differs from 2 to 6 feet, perhaps more in some places.

At Ovalumpilly Dr. H. found in the heaps of stones from the diamond conglomerate which had been examined, the following:—pellucid quartz, hornstone, a species of felspar; red, brown, bluish and black jasper; epidote, basaltic pebbles and sandstone; "small globular ironstone," fragments of corundum, and in the northern diamond mines, viz. at Partel, in the district of Masulipatam, pebbles of calcedony, cornelian, and garnets. (With reference to the origin of the pebbles of epidote, it will be remembered, that I have already alluded to the existence of a beautiful felspathic rock from the Rewa Kanta, composed of epidote and red felspar; from the same district, also, comes a trappean rock, the vesicular cavities of which are filled with epidote alone, or in part with zeolite. On the Southern Coast of Arabia, too, I frequently met with both these rocks, but the epidote was combined with calcareous spar instead of zeolite in the amygdaloid. Epidote appears to be by no means uncommon in the red felspathic rocks throughout India.)

VI.

Cretaceous System.

This system appears to have but a feeble representative in India, and to be entirely confined to the southern extremity of the peninsula, where a tract of limestone, containing fossils peculiar to the Lower Cretaceous and Upper Oolitic beds extends, from a point nine miles inland of Pondicherry to Trichinopoly, a distance of one hundred

miles, and perhaps still further. This is subdivided into smaller tracts by upheaval and denudation, as well as by the courses of rivers. It is stated that the fossils of the Pondicherry beds differ from those of the beds near Trichinopoly.

Newbold gives the following description of the limestone near the former—

"It is usually of a light brownish or grey colour, texture sub-crystalline, graduating into earthy; tough under the hammer, and inter-stratified with argillaceous and ferruginous beds; of a loose structure, which often abounds with fossil shells. Some parts of the rock are so speckled with a dark-coloured sand as to resemble a *piperino*, though the nature of the sand, whether volcanic or not, cannot be safely pronounced upon. Other varieties are hard and compact, enough to bear as fine a polish as many of our mountain limestones. It has been long used for the steps of doors, and in some of the pavements and old fortifications at Pondicherry; the remains of the old quarries are still to be traced, though choked up by rubbish."

It appears to rest on granite, hypogene, and greenstone rocks, unless these have been thrust into it.

Between the Velaur and the Coleroon river, Captain Lawford saw fossiliferous limestone beds, divided by a stratum of fossiliferous marl, about 4 feet thick: the lowest beds contained most fossils. At Garoodamungalum there is a ridge of blue fossiliferous limestone, which extends north and south for five miles each way, and at Valconda a calcareous schiste, also magnesite, the latter in loose nodules and masses, imbedded in the soil; hornblende rock also prevails.

The limestone of Trichinopoly is stated to be less crystalline, looser in texture, and darker in colour, than that of Pondicherry.

Of the collection of fossils from these beds which were presented to the Geological Society by Mr. Kaye and the Rev. W. H. Egerton, Professor Forbes, to whom they were submitted for examination and report, states as follows:—

"In the descriptive catalogue accompanying this report, and referring to remains of invertebrate animals in the valuable collection of fossils from Southern India * * * 168 species of Mollusca are enumerated, 156 of which, as far as can be ascertained, are undescribed forms. There are also a number of species of Radiata.

"The results of their examination may be briefly stated as follows:—

"1*st*.—The three deposits, viz. Pondicherry, Verdachellum [about thirty-five miles SW. of Pondicherry], and Trichinopoly, described by Mr. Kaye, are *Cretaceous*, inasmuch as there are characteristic known Cretaceous fossils in the collections from all of them, whilst no fossils of any other system occur. The nearest allies of the majority

of the new species are Cretaceous; and among the genera and subgenera are many which, as far as we know, are confined to, or have their chief development in the Cretaceous System. The three deposits are connected with each other zoologically by the associations of certain species common to two of them, with others found in the third.

"2*nd*.—Two of the three deposits, viz. Verdachellum and Trichinopoly, are of a different epoch of the Cretaceous era from the third, Pondicherry. The two former have several species in common (and those species among the most prolific in individuals), which are not found in the third. In them we found almost all the species identical with European forms. In several of the genera of which there are many species, the forms are altogether distinct, although, judging from the evidence afforded by mineral character and association of species, the conditions of depth and sea-bottom at the time of the deposition of the strata seem to have been the same. The difference, therefore, must have depended on a representation of species by species *in time*, and not *in depth*.

" 3*rd*.—The beds apparently contemporaneous, viz. Trichinopoly and Verdachellum, may be regarded as equivalent to the upper greensand and gault; the European species they include being either characteristic upper greensand and gault forms, or else such as occur in those strata. The species they contain are either closely allied to known upper greensand or gault species, or peculiar to the Indian beds.

"4*th*.—The Pondicherry deposit may be regarded as belonging to the lowest part of the Cretaceous System. In it almost all the fossils are new: such as are analogous to known species are allied to fossils of the lower greensand of English geologists, and Neocomien of the French. In the genus most developed in this deposit, viz. ammonites, three-fourths of the species belong to those subgenera especially characteristic of the "Lower Neocomien" of the Mediterranean basin; whilst of the remaining, as many representatives of Oolitic fossils occur as of upper greensand. The resemblance between the ammonites of this part of the collection and those of Castellane, in the south of France, is very remarkable, though the specific identity of any of them is doubtful. Having seen no account of the conchifera of the Castellane beds, I cannot say how far the analogy is borne out among the bivalve Mollusca, among the Indian species of which there are many very peculiar forms."

Of the collection of fishes' teeth made by Messrs. Kaye and Cunliffe in the neighbourhood of Pondicherry, Sir Philip Egerton states as follows:—

"With the exception of two specimens, the collection is entirely composed of teeth of Squaloid fishes. Of these two exceptions, one belongs to the Ganoid order, and to the family of *Pycnodonts*, and is probably a *Sphærodus;* the other is referred to the Cycloid genus *Enchodus*, the teeth very closely resembling those of *Enchodus halocyon*, a species common to the chalk of England, Continental Europe, and North America. Of the Placoid remains, two species only belong to the section of the Squaloid family, with serrated teeth, and both of them are referable to the genus *Corax*, which Agassiz informs us is restricted to the chalk. One species is not distinguishable from *Corax pristodontus*, of the Maestricht beds. The other is undescribed. The Squaloid teeth, with cutting edges, compose the bulk of the collection. They are referable to at least a dozen species, all corresponding, in the absence of plaits or striæ on the surface of the enamel. Although there are close approximations amongst them to the species both of the Cretaceous and Miocene period, yet it is somewhat remarkable that I have not seen a feature nor a character which recalls in the remotest degree the forms of the Eocene period. They belong principally to the *Odontaspid* type; one species being closely allied to, if not identical with the *Odontaspis raphaiodon* of the chalk of Europe. Two or three species are referable to the genus *Otodus*, one approaching *Otodus appendiculatus;* also from the chalk. Of the genera found in the Pondicherry beds, the following is the stratigraphical distribution assigned by Agassiz. The genera *Lamna*, *Odontaspis*, and *Oxyrhina*, extend from the recent period to the Greensand inclusive, the Jurassic species being now separated from Lamna under the generic title *Sphenodus*, and from Oxyrhina under that of *Meristodon*. *Otodus* extends from the crag to the Greensand, and *Corax* is restricted to the true chalk. The ganoid genus *Sphærodus* ranges from the Tertiary beds to the Oolite, and the Cycloid *Enchodus* is restricted to the chalk. The distribution of the species is as follow:—*Lamna*, 5 tertiary, 1 cretaceous; *Odontaspis*, 5 tertiary, 4 cretaceous; *Oxyrhina*, 11 tertiary, 2 cretaceous; *Otodus*, 8 tertiary, 5 cretaceous; and *Corax*, 5 cretaceous. Of the five Placoid genera we have 29 species occurring in the super-cretaceous, and 17 in the cretaceous deposits; but not a single species has yet been found anterior to the latter period. The evidence, then, afforded by the Pondicherry fishes, appears to yield strong corroborative testimony to the accuracy of Mr. Forbes' views, derived from the study of the invertebrate remains of the same locality, and I fully coincide with him in assigning these strata to the Cretaceous period. I am, however, inclined, considering the number of species collected, which must be referred to genera which we know decrease in species as they descend in the stratigraphical scale, from the occurrence also of Maestricht species, and from the

presence of the genera *Corax* and *Enchodus*, not yet found so low as the Neocomien, to place this deposit higher in the systems than Mr. Forbes is inclined to do from his investigation."

Both this and Professor Royle's reports on the fossils of these calcareous beds are only considered by their respective authors provisional. The descriptive catalogue mentioned by Professor Royle was not published, but figures and descriptions of the teeth examined by Sir P. Egerton accompany the observations above transcribed.

The following is a list of fossils which were also collected by Messrs. Kaye and Cunliffe, of the Madras Civil Service, from the same beds, and named by Dr. M'Clelland:—

Class ANNELIDES.

Fam. Serpulacea.

Serpula recta.

Class CONCHIFERA,

Fam. Arcacea.

Cuculla crassatina (?) Desh.

Arca Cunliffei.

—— *crassatina.*

Class CONCHIFERA.

Fam. Arcacea.

Nucula pectinata.

Fam. Malleacea.

Inoceramus.

Fam. Ostracea.

Ostrea trabeculata.

Gryphæa.

Class MOLLUSCA.

Fam. Calyptracea.

Pileopsis plana.—Same, or allied to shell in coal formation at Cherra.

—— *rotunda.*

Fam. Colimacea.

Bulimus Indicus.

—— *Pondicerianus.*

Fam. Melaniana.

Melaniana (?) Imperfect.

Fam. Peristomata.

Paludina. Allied to *Paludina semicarinata.* Brand. Desh. Coq. Fos. pl. xv. Species of this genus existing in India and elsewhere.

Obs.—It is much to be regretted, that the only specimen in the collection is not sufficiently perfect to allow of the species to which it belongs being accurately determined; but the presence of a fresh-water shell is important, as tending to show the deposit to have taken place near the mouth of a river, or in a basin alternately subject to salt and fresh water.

Fam. Neritacea.

Nerita transversaria. (Single specimen, imperfect.)

Natica sulculosa.

Nerita speciosa (?)

Fam. Scalariana.

Scalaria annulata.

—— *zonata.*

—— *bicostata.*

—— *tricostata.*

—— *Kayeii.*

Fam. Turbinacea.

Trochus linearis.

Fam. Canalifera.

Murex levis.

Fam. Orthocerita.

Baculites. Compressed, tapering, consisting of short joints; margins unequal, both somewhat flattened.

Fam. Nautilacea.

Nautilus. Three distinct species.

Fam. Ammonacea.

Ammonites.

"Echini, fishes' teeth, and Hamites, corallines of the Turbinalia species, and others of a pyriform shape. There are also shells of the families Myaria, Nymphacea

(Astarte), Cardiacea, Mytilacea, Pectinides, Ostracea (resembling Exogyra), Turbinacea (Turritella ?), Canalifera (Pyrula ?), Alatæ (Rostellariæ ?), Purpurifera (Buccinum), Convolutæ (Voluta ?), Ammonacea (Orbulites and Crioceratites). A number of sulcated cylindrical bodies, not exceeding the thickness of a quill, of different lengths, but generally from 2 to 3 inches long, and in all cases broken off, are scattered in the substance of the rock. They resemble somewhat the spines of echinites. There was also a fossil vertebra found, which Professor Owen pronounces to resemble that of Mososaurus."

It should be remembered, that although the limestone beds in the southern extremity of India have all been placed in the cretaceous group, yet that Professor Royle found in the collection of fossils from Pondicherry three-fourths of the ammonites especially characteristic of the Lower Neocomien; while of the remaining, as many representatives of Oolitic fossils occurred as of upper greensand; and hence, that a part of these beds may belong to the Oolitic Series.

VII.

Eocene Formation.

The most southern position in which this formation would appear to exist in India is in the westernmost spurs of the Rajpipla hills, which form the left bank of the valley of the Nerbudda, about 50 miles from the sea. It would appear also to exist in Bate Island, which is situated at the north-western extremity of Kattywar; but the presence of more fossils, if not of nummulites, is required, to prove that these are not deposits of the Miocene age.* Cutch is the most southern

* I have since discovered the following nummulites in the Rajpipla Limestone, and we shall presently see that not only the limestone from Bate Island, but also the limestone charged with *Orbitolites*, Lam. on the west coast of Khattywar, must be included among the Eocene Strata.

Nummulites (Ramondi, *mihi*). Discoidal, thick; margin angular acute, slightly wavy. Surfaces smooth, marked with lines for the most part simple, radiating from the centre to the circumference. Spire very regular, consisting of nine whorls; chambers also very regular, a little longer than broad, reflected; septa slightly curved. Diameter $\frac{9}{48}$ inch, thickness $\frac{3}{48}$ inch. *Loc.*—Wasna in the Rajpipla Hills near Broach. In red and yellow, compact, earthy, argillaceous limestone.

Obs. This beautiful little nummulite closely resembles *N. Ramondi*, Def. (Foss. Num. de l'Inde, pl. vii. fig. 13). It is associated with *Operculina*, *Orbitoides dispansa*, and small shells. From being imbedded in a ferruginous rock, the parts which contained animal matter have become red, while the rest remains white, hence its beautiful appearance. Having had to examine it by sections, I have observed that the parts covered with and permeated by that substance which I have compared to the "cuticle of shells" (but which the authors of the work just mentioned more properly liken to the epidermis of the echinides and epitheca of polypes), are infiltrated with red oxide of iron; the interseptal spaces white, but the interseptal vessels or canals red; the marginal cord white, but presenting in its transverse section red points showing the position of marginal canals; and the external surface of the cord traversed by longitudinal lines indicative of the previous existence of spicula, such as I have described in *Operculina Arabica*. Ann. and Mag. Nat. Hist. vol. x. p. 161.—1852.

Independently of MM. le Vicomte d'Archiac and J. Haime having stated, p. 54, "Or, nous

province in India where the existence of nummulites has satisfactorily established that of the Eocene Formation, and here it only exists in a small tract; from which, however, it is probably continued on, under the alluvium of the Indus, to the neighbourhood of Hyderabad, where it again appears to a much larger extent; also extending between Roree and Dajikote, and probably under the alluvium on to Jessulmeer in the Great Desert, if the yellow limestone of this place, which is the same as that chiefly used for tombstones in Lower Sinde, belongs to the Nummulitic Series.

Nothing more is known of this formation at the Rajpipla hills, or in Bate Island, than that we possess several specimens from the former charged with *Orbitoides dispansa*, which were presented to the museum by Major Fulljames; and specimens from the latter pregnant with the cast of nummulitic fossils (large *Cerithiadæ*), which were presented by Lieutenant Taylor, of the Indian Navy. We have also several specimens of limestone from the north-western third of Kat-

nous sommes assurés, par des observations très-multipliés, que dans aucune des espèces de ce dernier genre [Nummulites], il n'existe rien qui puisse rappeler la corde spiculaire ni le plexus marginal signalés par M. Carter dans l'Operculine d'Arabie,"—I have had here the opportunity of comparing an *Operculina*, closely allied to *O. Arabica*, which happens to be imbedded with this nummulite, and precisely in the same condition as regards ferruginous infiltration; and on the surface of the marginal cord of the former are beautifully shown the longitudinal lines indicative of the presence of spicula, which, when placed side by side with the nummulite, only exhibit the difference that they are a little more faintly marked in the latter. Both these fossils are most favourably circumstanced for exhibiting the points mentioned; they are hard but in a comparatively soft matrix, which renders their extrication easy without scratching, so that they fall out with shining surfaces; both are beautifully regular in structure; and the contrast between the red infiltrated parts and the crystalline white ones enables the observer to distinguish the limits of the two in both, with the greatest nicety. No one can witness them in comparison with recent *Operculina*, without feeling convinced that the red parts in the former and the green ones in the latter were formerly occupied by sarcode; that the sarcode permeated the walls of the chambers and formed a soft substance on the surface; any more than that the spicular cord existed in all three, as represented by that ridged surface shown so distinctly in Dr. Carpenter's figure of *N. lævigata*, 7 *c*, pl. iv. *loc. cit.*, and with the openings of canals from the marginal plexus in MM. d'Archiac and J. Haime's fig. 1 *e* of the same nummulite, pl. iv., also *loc. cit.* I have also lately noticed, that in some specimens of *Operculina Arabica*, the spicular structure is not only present on the margin, but is extended inwards over the interseptal spaces between the last five or six chambers.

Nummulites Broachensis, H. J. C. (*nov. sp.* ?) Discoidal, thick; margin angular, acute. Surface smooth, presenting punctæ arranged spirally without striæ. Spire regular, consisting of six whorls; chambers longer than broad, septa reflected, curved. Diameter $\frac{5}{48}$ inch, thickness $\frac{2}{48}$ inch. *Loc. idem.*

Obs. At first I thought all the little nummulites in this argillaceous limestone were the same, but the former evidently belongs to the *plicatæ et striatæ*, and the latter to the *punctulatæ* (d'Archiac et Haime); and answering to none of their species, from the spiral arrangement of the punctæ without striæ, I have taken the advantage of giving it the above specific designation, to record the fact of the existence of Eocene Strata near the town of Broach, about fifty miles up the river Nerbudda.

tywar, which seem from their structure to belong to this formation; but this is all that can be stated of them, for they contain no fossils which are recognizable.

The only tract of nummulitic limestone, according to Colonel Grant, which exists in Cutch, is situated in its north western-extremity, near the mouth of the eastern branch of the Indus, where it appears to have dwindled away to a mere remnant, unless it was never very much larger. It extends from Luckput southwards for thirty miles, and its northern, which is its widest part, is eight miles across. Where small sections of it present themselves, as in the banks of rivers, it consists of solid rock, of a cretaceous appearance, 60 or 70 feet in thickness, filled with *Nummulites*, *Fasciolites*, and *Orbitolites* (*Orbitoides* in the illustrations); in other parts it consists of "nummulitic marl," of the same depth. It is overlaid by loose fossils, and detached portions of its own surface, or by a thin stratum of gravel.

Near the hill called Baboa, the nummulitic marl is cut through by a dike of "very compact dark green basalt," of which conical masses, capped with the marl, are undergoing spheroidal desquamation and decomposition at the line of contact between the two.

The nummulitic limestone of Sinde, that is to say at Hyderabad, which projects about 60 feet above the level of the alluvial plain, is solid, white, and cretaceous above, where it is richly charged with *Fasciolites elliptica*, and other nummulitic fossils, and yellow, plastic, and marly below. I failed to discover any nummulities in either portion.

At Sukker, the range of nummulitic hills, which, according to Dr. J. P. Malcolmson, do not exceed 400 feet high, are composed of friable or compact limestone, of a white or cream colour, resting on yellowish, white plastic clay; the former richly charged with *Nummulites*, and plentifully interspersed with flints, which also envelope *Nummulites* and *Orbitolites Mantelli*, H. J. C.,* that are silicified.

The following section comprises the three last divisions of that deduced by Captain Vicary from an examination of the beds about Kurrachee, and the composition of the Halla range; the other part of the section will be given under the head of "Miocene and Pliocene Formations":—

"Pale arenaceous limestone, with hypponyces, nummulites, and charoideæ.
Nummulitic limestone of the Halla range.
Black slates, thickness unknown."

* * * * * * * * *

At Muskat, on the coast of Arabia opposite Sinde, there is a very clear section of this series exposed in many places, in the sea-cliff.

* *Orbitolites Mantelli*, H. J. C., and *Orbitolites*, Lamarck, are different; see pp. 547 and 594.

It consists superiorly of coarse limestone, of a yellowish white colour, from 60 to 100 feet thick; then arenaceous limestone, containing a great many corals; afterwards this passes into sand, with veins of gypsum; and the sand again into beds of pebbles resting on serpentine rock with pinch-beck diallage, or on diorite. In this series, at Muskat, Newbold found a bed of nummulites, which I had not the good fortune to see during my examination.

A similar section is seen in the island of Masira, resting here, also, on diorite and serpentine rocks; but the pebble-bed seems to be replaced by red and dark-coloured clays, which, from their appearance, indicate a conformable transition of the latter into the former. The arenaceo-calcareous strata in one part of this island abound in nummulites of a similar kind to those which Newbold found at Muskat.

On the mainland of Arabia, opposite the south-western extremity of Masira, is another section of the kind, but here the deposits are more or less white. The limestone, which is about 150 feet thick, rests on a greenish-white clay.

Does this marl or clay, or sandy deposit, which underlies the nummulitiferous limestone respectively at Muskat, Masira, on the mainland of Arabia, in Cutch, and in Sinde, limit the vertical extent of the nummulitic beds?*

* * * * * * * *

For the fossils obtained by Colonel Grant from the nummulitic formation in Cutch, and which have been described by Mr. J. de C. Sowerby, see *antè*, p. 450, and pl. xviii.

So far, my observation of the fossils which have come from the nummulitic formation in Sinde, leads me to the opinion that they chiefly differ in specific characters, from those of the Paris Basin which have been figured by Deshayes, and that very few new genera will be found among them. Some of the limestone at Hyderabad is remarkably like the "Calcaire grossier."†

Although the fossils are abundant almost beyond conception, yet they are mostly useless for description, on account of being the internal casts, and not the petrified remains of the shells they represent.

* The two following paragraphs, which contained a conjectural answer to this question have been omitted. It is now decided in the affirmative; the Nummulitic Series does terminate here; and on the south-east coast of Arabia the Cretaceous Period would appear to begin in the descending order, with the white limestone which forms the summit of the table-land (see the foregoing Memoir).

† Since this "Summary" was written, the valuable and beautifully illustrated work on the "Animaux fossiles du Groupe Nummulitique de l'Inde," by the authors M.M. le Vicomte d'Archiac and J. Haime, has appeared, to which I have had frequent occasion to allude, and for which it is little in return to state, that it is as indispensable to the student of Geology in Sinde as it is to those who would make themselves acquainted with the Eocene Group generally, wherever they may be situated.

There appear to be only two species of *Nautilus:* at least out of 180 specimens collected from all parts, I have only met with that number, viz. 150 of one and 30 of the other. The largest is the scarcest.

As they do not appear to have met with descriptions, the following may prove acceptable :—

Nautilus major, H. J. C. (Cast.)—Suborbicular, discoidal, compressed; margin angular; widely umbilicated; sutures undulous, doubly sigmoid; siphon ventral. *Size.*—Longest diameter of largest specimens 12 inches; largest transverse diameter upwards of 6½ inches.

Obs. This species, from its angular margin, resembles, in form, the subgenus *Goniatites* among the *Ammonites.* In the position of its siphon, it agrees with *Nautilus zigzag,* but its sutures are simple, like those of *N. Danicus.* I have never seen a specimen of *N. zigzag* from Sinde, though we have one in the museum which Professor Orlebar brought from the Eocene of Egypt. *N. major* must, I think, be the largest nautilus on record.

N. minor, H. J. C. (Cast.)—Subglobular; margin round; umbilicated; sutures subsigmoid; siphon ventral. *Size.*—Longest diameter 3 inches; largest transverse diameter upwards of 2¼ inches.

Obs. This species agrees with *N. hexagonus* in the position of the siphon and form of the suture; but it differs from it in not having a sulcated keel or margin.*

For descriptions of most of the largest forms of fossilized Foraminifera in Sinde, see p. 533.

As yet we know nothing definite of the nummulitic formation of this country, although its features are so striking, that the most disinclined

* The first of these *Nautili* is *N. Deluci,* d'Archiac, pl. xxxv. figs. 2, 2 *a,* and the second *N. Labechei,* d'Arch. et J. Haime, pl. xxxiv. figs. 13, 13 *a,* and pp. 337, 338, *op. cit.* In examining a specimen of the former, I have just had the good fortune to discover that the contents of the last chamber are charged with *Cyclolina* and *Alveolina elliptica;* I state "good fortune," for it will have been seen that by following M. Alcide d'Orbigny's "Tableaux" (Cours Elément. de Paléont. &c.) I have made it the signal for recognizing the commencement, in the descending order, of the *Cretaceous Series* on the South-east Coast of Arabia, whereas it is by no means limited to this period. At first I thought, from the great resemblance of *N. Deluci* to *N. triangularis* of the Cretaceous Series, that they might be the same, and that probably the hills about Hyderabad in Sinde where I had found N. *Deluci in situ,* and had not observed nummulites, might be a part of the cretaceous deposit; but on examining specimens of the limestone charged with *Cyclolina pedunculata* from the Buran river not more than thirty miles from Hyderabad, I find that there are also many small nummulites present very like if not the same with *N. latispira,* Menegh. (Foss. de l'Inde, pl. i. fig. 6); while in limestone bearing the same species of *Cyclolina* from other but unknown parts of Sinde, there are small nummulites of the group *Punctulatæ.* Now, the *Cyclolina* in all being the one mentioned and hardly deserving of a different designation from d'Orbigny's *C. cretacea,* while it has been found throughout the Cretaceous Series on the South-east Coast of Arabia, it follows, that this fossil has, perhaps, the widest range as to time of all the larger species of Foraminifera, and also that the summit of the great scarp on the South-east Coast of Arabia is by no means so evidently confined to the Cretaceous Series as d'Orbigny's range of *Cyclolina* had led me to infer.

for observation or the study of natural objects come away from Sinde astonished at the geological sections of its rocks, and the vast quantity of organic remains which are distributed over them.

VIII.

Volcanic Rocks.

Trappean System, 1st Series.. { *Trappite.* *Basalt.* *Amygdaloid.* *Laterite.*

Subsequent to the deposit of the Punna Sandstone, or the last bed of the Oolitic Series, in the interior of India, a succession of trappean effusions took place.*

These were more profuse in some than in other parts, and, generally, more extensive, as the existing tracts and weathered blocks, which are scattered over many plains, respectively testify. The trappean dikes, too, which exist throughout the greater part of India, from the summit of the highest mountains (Neilgherries) to the level of the sea, and the crystalline metamorphosed state of the upper part of the Punna Sandstone in many places,—apparently from heat applied to the surface,—all tend to the inference that the trappean effusions extended over a much greater part of India formerly than at the present day.

The largest tract remaining is that on the western side of India, but sufficient time has elapsed since the last of *its* effusions were poured forth to weather down its cones, efface its craters, dissipate its scoriæ, break up its plains, and transform its surface to such an extent, that from an arid, black, undulating volcanic waste it has now become a tract of mountains, hills, and valleys, covered with verdure and cultivation; and with the exception of the crater of Loonar, without a known trace of any vents, to point out the localities from which the volcanic matter of which it is composed was ejected.

This tract, called by Malcolmson the "Great Basaltic District of India," extends continuously from the western side of the basin of the Malpurba, in the Southern Mahratta Country (P.MS. Aytoun), to Neemuch, on the extreme northern limit of Malwa (Dangerfield); and transversely from Balsar, on the coast about twenty miles south of the Taptee (Lush), to Nagpore in Central India (Malcolmson). These are its extremes north and south, and east and west; the former a distance of about 535, and the latter one of 350 miles. Between Balsar on the west and Nagpoor on the east, it contracts northward to a

* May we not say subsequent to the Eocene Period, as the trappean effusions have evidently raised up the serpentine and diorite rocks on which the strata of this era were deposited on the South-east Coast of Arabia?

width of only eighty or ninety miles, where the Nerbudda crosses it between Chiculdah and Burway (to mention the large towns close to its limits). After this it again expands out to form the tract of Malwa, which extends eastwards to Tendukaira, about seventy miles west of Jubbulpore, and westwards to Tandla (Dangerfield). From Nagpore south-west ward to Beejapore it is bounded, as in Malwa, by an irregular and more or less abrupt border; and its coast-limits are Balsar in the north and Malwa in the south.

There is another portion, which extends eastward from Jubbulpore to Amerkuntak, the source of the Nerbudda (Spilsbury), and south-west towards Nagpore (Franklin); but I am ignorant if this joins the main tract.

As there is necessarily a great sameness in the trappean effusions throughout India, wherever they exist to any extent, we shall take our typical characters from the great district just described; and even here, a part would seem to suffice for the whole, for the remarks of Dangerfield on it in Malwa, of Coulthard in the adjoining district of Saugor, and of Sykes, Malcolmson, and Newbold in the Deccan, are, though all valuable and indispensable, but repetitions of each other.

Its two grand geological features along the anticlinal axis of the Western Ghàts, where it has attained the highest elevation, are flat summits and stratification. The latter arises from the alternation of compact and amygdaloid layers, which, on weathering, give to its lateral outlines that irregular step-like form, from which the trappean effusions have derived their name. Captain Dangerfield numbers "fourteen beds" in Malwa, the lowest and largest of which is 300 feet in thickness. These are equally numerous, if not more so, along the Western Ghàts, where the scarps are of much greater magnitude: that of the pass of Ahopeh is, according to Colonel Sykes, "fully 1,500 feet high, and that of Hurrichunderghur, about twenty miles north of it, scarcely less than double that height." The mountain of Mahableshwur is from 4,500 to 4,700 feet above the level of the sea. From these summits the trappean district slopes off suddenly on each side, but more abruptly towards the west, where it reaches the level of the sea within forty or fifty miles of the anticlinal axis.

Besides its stratification, it presents in many places, on closer inspection, a columnar structure, which is chiefly confined to its compact beds, and which seems to have been more frequently noticed on the summits of mountains, and in the beds of valleys and watercourses, than in any other part. Thus Colonel Sykes mentions a surface of pentagonal divisions in the hill-fort of Singhur, which is 4,162 feet above the level of the sea; also in the hill-fort of Hurrichunderghur, just mentioned; while Captain Dangerfield mentions them in the bed

of the Chumbul and Nerbudda rivers. They are common on the surface of the overlying trap of Bombay, but with the lower part so continuous and so stratified, that, like that described by Newbold in the bed of the Hurri, near Beejapore, its divisions into "rectangular and rhomboidal prisms are similar to those of clay slate." Voysey has noticed its columnar form in the upper part of the hill of Sitabaldi, which is close to Nagpore, and Malcolmson on the elevated lands and crests of the Sichel Hills. Many other places might be mentioned where this structure occurs in like situations, but very few where it has been seen in the body of the mountains.

Wherever the trappean effusions exist to any extent, they appear to be composed of the rocks mentioned at the beginning of this group, viz. *Laterite* above, then *Basalt*, and afterwards *Trappite* and *Amygdaloid*, with here and there volcanic breccia. Where the trappean rocks are genuine, that is where they are neither mixed with foreign matter nor decomposed, they are chiefly compounded of hornblende and felspar, but differ from the diorites or greenstones, as before mentioned, in the former being finer in structure, less crystalline, and generally containing a portion of greenish, bluish, or reddish earth, according to the colour of the rock, in addition to their crystals of hornblende and felspar. The latter is never the case with diorite, and is, therefore, perhaps, the best distinguishing feature, but it can only by detected by a powerful lens. The diorites appear to have gained their coarseness of structure and more crystalline nature chiefly from the length of time they have been exposed to the percolation of water, while they have been totally excluded from the atmosphere. There are, however, fine black, red, and green, coarse crystalline hornblendes, here and there, among the trappean rocks, which, in hand-specimens, would almost defy the best judges to say whether they are not diorites or amphibolites, but they are only of casual occurrence.

Before proceeding to particular descriptions of these rocks, it would be as well to devote a few moments to the consideration of the facts which bear upon the relative ages and positions of the trappean effusions. It should be remembered that there is this great difference between the superposition of aqueous and igneous formations, viz. that the former must have been increased in thickness by successive additions to their surface, and that the latter may be increased in thickness by additions also below their surface; the material in the one case coming from above, and the material in the other from below. Hence circumstances may so favour a horizontal extension, and oppose a vertical ascent of the latter, that it will be found in some places intercalating the interior of volcanic mountains which have been formed, long anterior to its ejection. At the same time, this intercalation must

have taken place before the whole tract was broken up, or the circumstances favouring it would not have been present. It is not our object here to enter into the theory of the elevation of the Western Ghàts, or of any other parts of the trappean district, but to try to acquire some idea, if possible, in the present state of our knowledge, of the relative ages of the effusions of which it is composed. One fact seems evident, viz. that there is an overlying basalt, which, generally capped with laterite, rests on the summits of the highest mountains, and on the tops of the lowest hills; and that the former are separated from each other by such wide and such deep valleys, that they never could have been capped with the same material, had they not all been united into one mass when the basalt and laterite were poured forth. The trappean effusions, then, had probably attained their greatest thickness along the anticlinal axis of elevation, that is, along a line a little to seaward of the Western Ghàts, before this took place, for here the mountains being highest and most separated, exhibit a thickness of trappean rocks far greater than in any other part; which tends to these inferences, viz. that in this direction there was a line of vents; that the greatest and latest effusions from them preceding the elevation of the Ghàts, made the trappean rocks thicker here than in other parts; and that along this line of vents the subterranean force which elevated the Western Ghàts was most likely to be exerted. But it does not follow that the overlying basalt was the last effusion, for the intercalation of subsequent ones may have added, as I have before stated, considerably to the thickness of the general mass, before the grand disturbance occurred which threw the whole up into mountains; while there is evidence, as we shall see hereafter, of many minor effusions having occurred since this epoch.

With these few prefatory remarks, let us proceed to the description of the trappean rocks separately.

Trappite.

This rock is semi-crystalline, and consists of felspar and hornblende in nearly equal proportions, with a little argillaceous matter. Its structure is massive, and its texture visible only under a high magnifying glass, when the ingredients of which it is composed also become recognizable. It is tough towards the surface, and softer below, where it breaks with a granular earthy fracture, sometimes conchoidal. It is of a black, red, bluish, or greenish-blue colour; is easily scratched with a knife; disintegrates in polyhedral masses, undergoing concentric-lamellar decomposition, and finally passing into a greyish or greenish-brown earthy mass, which has been called wacken.

The reader will do well to remember, that wherever "wacke" or "wacken" is here mentioned, it means decomposing or decomposed

trappean rocks. The name "Trappite" is taken from Brongniart's classification, to which I have already alluded, but it contains no mica.

Basalt.

There are two kinds of this rock which deserve particular mention: one is for the most part of a dark blue-black, and the other of a brown-black colour. Both are semi-crystalline, like the last rock, and composed of felspar and hornblende, or augite, with probably a little amorphous, argillaceous matter. Their structure is massive, stratified, columnar, or prismatoidal; and they are tough, and tesselated towards the surface, but frangible below. They disintegrate in polyhedral masses, which undergo infinite divisions, and, desquamating in concentric laminæ, assume the form of a bed of rounded nodules of various sizes, and of a greenish-brown colour, becoming smaller and more numerous as they pass into an earthy wacken, in which all traces of the hard rock disappear.

a. Dark blue-black basalt of the island of Bombay. This is so compact that its ingredients cannot be distinguished, even with a lens. Its structure is remarkably stratified, almost like clay slate; it breaks with a subgranular, conchoidal fracture; is avesicular, but contains here and there a small mass of pale crystalline olivine.

b. The brown-black basalt of the Deccan. This is subgranular, and the ingredients of which it is composed more or less visible; it is tough, and breaks with a subgranular fracture; is avesicular, but presents many scattered masses of olivine; it is of the same kind as the basalt of the "Pouce," in the Mauritius. Sometimes the olivine seems to pass into glassy felspar, and then to form a great part of the rock.

That the first kind belongs to the overlying basalt, there can be no doubt; and from Voysey's having likened the overlying basalt of the Gwailgurh hills to that of the "*Pouce*" mountain, in the Mauritius, there can be little doubt, also, that the second form is also to be found in the overlying basalt. At the same time, it would be very desirable, as will hereafter appear, to ascertain if the different forms of the overlying basalt possess any peculiarities which distinguish them as a group from the other trappean effusions.

Both the *Trappite* and *Basalt* are tesselated on the surface by cracks and veins, which would seem always to be present throughout their structure, though not always visible; those of the basalt tend most to a prismatoidal arrangement. Both, too, even in their massive forms, present accessory minerals here and there: in the basalt these consist chiefly of small masses of olivine, and in the trappite chiefly of zeolites. The position and depth of the basalt appears to be overlying and thin, and that of the trappite for the most part inferior and thick; the

structure of the former more or less prismatoidal, that of the latter more or less irregular. Occasionally the texture of these rocks is a little finer or a little coarser, a little more crystalline or a little more earthy.

Amygdaloid.

This is only a variety of one or the other of the foregoing rocks, but it is convenient to give it a specific name. With more or less of their characters, though never strongly marked, it is also more or less cavernous or vesicular, and the minerals which fill or line its cavities very various, while some appear to be peculiar to a trappitic, others to a basaltic base. Green earth, zeolites, calcspar, and calcedony or quartz appear to prevail in the former, and olivine, glassy felspar, and magnesia-mica in the latter. To each of these minerals we shall now turn our attention separately, as upon the prevalence of one or the other depends greatly the character of the amygdaloid; and those found in a trappitic or earthy base being most numerous, we will take them first.

Minerals of the Trappean Rocks.

Green-Earth.—There is no mineral in the amygdaloids which is more general or more striking at first sight than this, from its bright blue green colour, and its frequent occurrence. It prevails chiefly in the red amygdaloids, lining their cavities, or mixed with the minerals which they contain, but never entering into a part of the composition of the latter. Nicol places it among the clays. It appears to be amorphous, is greasy to the touch, sectile, and presents a shining streak when scratched with a smooth-pointed instrument. Its colour is apt to mislead those unacquainted with its elementary composition, into thinking it contains copper, but iron and manganese are the only metals which have been found in it.

Zeolites.—Next in prevalence are the following minerals of the zeolitic family, which is, perhaps, as well, if not better represented in India than in any other part of the world:—

Scolezite is probably the largest and most plentiful of these, occurring in compact or crystalline, columnar, radiating masses, white, or of a pinkish tinge, opaque or translucent, and in small crystals transparent; in some specimens the radii are from two to three inches in length. *Natrolite* or *Mesotype* in mammillary masses of fine prismatic or acicular crystals, sometimes asbestiform; it occurs at Akulpore, in the Southern Mahratta Country, in radiating columnar masses, extending six or seven inches from the centre (Sykes). *Apophylite*, in thick rectangular prisms with truncated or pointed summits, is very common; opaque or translucent; when the summit is perfect, the latter is generally transparent; cleavage across the prism (macrodiagonal), leaving a

pearly surface; it also occurs foliated and massive. *Stilbite*, in compressed rectangular prisms, terminated by four narrow facets, is also very common, occurring in radiated, fan, sheaf-shaped or scopiform aggregates on free surfaces; semi-transparent, like crystallized spermaceti; also occurring in radiated masses of a white or pinkish colour, like scolezite, but with a laminar-columnar arrangement; cleavage longitudinal, parallel with the compressed planes, leaving a pearly surface; perfect crystals rare with the aggregates; occurs frequently on apophylite in geodes. *Heulandite*, in compressed lozenge-shaped crystals, aggregated, and standing on their edges, with the upper angle replaced more or less by a facet on each side, and the free terminal one generally truncated. *Chabasite*, in very obtuse rhombohedrons, scarcely differing from a cube; glassy, pearly, greyish, yellowish, reddish. *Phrenite*, of a sea-green colour, is not uncommon, crystallized on zeolites in round ed aggregates.

From the pearly cleavage of most of these minerals, it is difficult to say which is which in their amorphous masses, or when they fill the vesicular cavities of the amygdaloid.

Laumonite appears to be the commonest zeolite in the neighbourhood of Bombay, occurring in oblique rhombic prisms, of which the inclination of the terminal plane is from one acute angle to the other, one of those angles being replaced by a facet. It is translucent when first exposed, but becomes opaque, white, and brittle in a short time afterwards; this renders it easy of recognition.

Quartz.—Almost all the varieties of this family occur in the trappean rocks, but chiefly in large crystals in geodes, colourless or amethystine; also in small crystals forming stalactitic, finger-like prolongations, and capping large pyramidal crystals of calcspar in geodes. Calcedonies, agates and onyx which also abound, belong to this family.

Calcspar.—This occurs in rhomboidal masses, and in pyramidal crystals projecting into the interior of geodes. The latter seems to have been a very early crystallization, which has not only been succeeded by the capping of quartz just mentioned, but this capping itself is in most instances more or less hollow, from the re-absorption of the calcspar. The pyramidal form of calcspar had a great development at one time, for its crystals, now only represented by the quartz, far exceed in size those of any other trappean mineral. The rhombohedral masses are of three kinds, viz. colourless, hair-brown, and green; the latter is found in portions of 2 feet in diameter, in amygdaloid forming the bed of a river near Gorgaum, north of Akulkote, in the Southern Mahratta Country (Newbold); also in the Buktapore hills near Kowlas, about thirty miles NNE. of Beedur (Voysey); and Grant mentions

"thin beds or layers" of leek-green calcspar in an amygdaloid in Cutch. Besides these various other forms of calcspar occur, but the ones mentioned are the most prevalent. Perfect crystals of both pyramidal and rhombohedral calcspar resting on zeolitic minerals are not uncommon in geodetic cavities.

Olivine.—This mineral, as I have before stated, is almost peculiar to the basalt, and is but sparingly scattered in the overlying portion. It, however, frequently forms part of an amygdaloid, with a black compact base, and when mixed with *Rubellan*, seems to depart from its original faint colour to become of a greenish yellow, pistachio-green, brass or bronze yellow, brown, pitch-black, or brown-red tint.

Glassy-felspar.—A porphyritic amygdaloid with a similar base to the foregoing, and thickly charged with tabular crystals of this mineral, is very common, the crystals having a vitreous lustre, and a faint yellow colour; but, when they occur in a reddish base, they have a whitish colour and pearly lustre.

The black porphyritic form exists in a thick stratum on the summits of Hurrichunderghur and Poorundhur, which are 4,000 feet above the level of the sea; also in the bed of the river Goreh, which is elevated 1,000 feet above it, near Seroor (Sykes). Dangerfield also states that at Cherole and Kuchrode, in Malwa, there " are some large overlying masses of trap porphyry," which is probably the same as the one described; and in the Society's museum are specimens from Khandeish (Aytoun), the neighbourhood of Poona (Malcolmson), and Belgaum (Aytoun). Olivine occasionally appears to pass into glassy felspar, and then the latter, as I have before stated, increasing in quantity, to form, in an amorphous crystalline state, a large portion of the elementary composition of the basaltic rock.

Magnesia-mica.—Accompanying the glassy-felspar are small laminated masses of a substance like mica, which are either separate, or in the midst of the tabular crystals of felspar. Its chief characters are its scaly, foliated, laminar form, rich brown-red colour, shining lustre, and softness, being easily scratched with a knife; but in its fracture it is less flexible than mica, if, indeed, it have any flexibility at all.

Besides this form, it appears to occur in a massive, crystalline, transparent or opaque state, partially or wholly filling small vesicular cavities, and presenting a bloom on its free surface. When translucent, it is of a hyacinth-red, peach-blossom, or red-brown colour, and when opaque of a blood-red, dark brown-red, dark olive, or pitch-black colour like obsidian, to which it seems nearly allied. In the latter state it may also form a continuous scaly layer on the free surface of the basaltic rock.

It frequently coats the surface of the tabular crystals of felspar and

olivine, and on the other hand lines vesicular cavities, like green-earth, to which in these instances it also appears to be closely allied.

When the tabular aggregates of this mineral lose their lustre, they assume the form of *Rubellan;* when it has a strong metallic lustre, it looks like *Rutile.* In another form, which I have not mentioned, it has a waxy appearance, and greenish-yellow colour, like serpentine. Its colouring matter appears to be chiefly iron, which in the metallic varieties is easily detected by the blow-pipe and magnet. Sometimes this magnesia-mica or *Rubellan* seems, in minute crystallization, to form the greater part of the base of the red amygdaloids, and on decomposing assumes the form and appearance of red clay. If the *Rubellan* of Breithaupt be magnesia-mica, as Nicol seems to think, then this mineral is magnesia-mica; but it requires further examination.

Besides the substances above mentioned, there is a fine red clay, of a compact, massive, or columnar structure, which is found in subordinate masses in the amygdaloids, sometimes pure, at others containing zeolites.

In this hasty outline of the minerals contained in the amygdaloid rocks, I am of course only describing the general characters of the amygdaloids themselves, and, therefore, must leave the reader to search for further details respecting these minerals in works especially devoted to the purpose; at the same time observing, that a separate description of them and their pseudomorphs, which have not yet been mentioned, would form a most interesting and valuable contribution to the mineralogy and geology of India.

Of these pseudomorphs I need only notice here the passage of the radiated forms of zeolites into steatitic clay or steatite, and of glassy-felspar, by transition, into the latter; also the replacement of calcspar by crystalline quartz.

Basaltic Dikes.

These are of course numerous in the trappean tracts, as well as elsewhere, and their structure prismatic and compact where they are not decomposed, the columns being perpendicular to the surface planes. Colonel Sykes mentions one which cuts through the basalt and amygdaloid in the top of a mountain within the hill-fort of Hurrichunderghur, which, as before stated, is 4,000 feet above the level of the sea. He also mentions dikes in the hills about Poona and the Bhore Ghàt. All these must of course have existed before the trappean plains were broken up. Mention is frequently made of basaltic mountains, which are completely isolated from the main tract by a vertical fissure or ravine with perpendicular sides, of only a few feet in breadth, and of a great depth. These may have been formed by dikes of more perishable matter, which have become decomposed, and carried away by the rains.

Laterite.

This rock, *par excellence*, that is where it caps the trappean mountains, is essentially composed of red iron clay, the iron of which, by means of segregation, has formed itself into cells and irregular tubes, chiefly at the expense of the clay which is contained in their interior; hence the lightness in the colour, diminished quantity, and soft and greasy nature of the latter, whilst that on the exterior of the tubes remains red, and retains its original harshness to the touch. This causes the white and red colour in the rock, and is a process which appears to be continually in operation. The inner surface of the tubes is smooth, and frequently mammillated, and the exterior, of course, rough; while their walls are composed of brown hematite, presenting more or less of a metallic lustre. A steel-grey oxide of manganese (Pyrolusite) not unfrequently takes the place of the oxide of iron, or, mixing with it, forms the greater part of the mass, and the purple violet tint which this rock sometimes assumes, Newbold thought might be owing to the presence of the former. The contorted, irregular tubes, which are frequently so numerous and near together as to give the mass a cancellated structure throughout, are generally about half an inch in diameter, but vary every moment, in contracting and expanding to much beyond or within this size. They also frequently inosculate with each other, but seem, on the whole, to have a vertical direction, if we may take our type from the laterite at Beedur (Voysey). At this place, also, Newbold traced one downwards for 30 feet, which, after all, opened on the side of the rock. Sometimes the whole mass passes into pisiform iron ore without the tubes (Mm. Bradley). When exposed to the air, its surface becomes black, and presents the black or iridescent metallic lustre common to some forms of brown hematite.

Laterite of this composition and structure caps the highest trappean mountains, terminating in level summits. At Mahableshwur it appears to be at least 100 feet thick, and at Beedur, on the opposite or eastern confines of the great trappean district, is in one part 200 feet deep (Newbold) where it rests on wacken passing downwards into basalt (Voysey). Whenever it appears on the trappean rock, whether in Malwa, at Ammerkuntak (the source of the Nerbudda), on the Rajmahal hills, or in the Southern Mahratta Country, it presents the characters above given, and always rests on what has been termed "overlying trap." It by no means, however, exists continuously throughout the great trappean district, but chiefly on the summits of the highest mountains, where its scarped sides (like those of the overlying basalt beneath it) and horizontal summits characterize its presence from a long distance.

Various opinions have existed respecting the origin and geological

age of the "laterite," but I shall only mention here those which appear to me most rational, and most in accordance with my own observations. Voysey and Christie classed it with the overlying trap, and Voysey made the following note upon it, dated 26th September, 1819, viz. :— "I commenced on the hill of Beedur, and this morning rode to the north-westward. I everywhere saw basalt at the foot of the hill, passing into wacke and iron clay; in one place the transition did not occupy more than 3 feet, and was distinct."

Few, who know the penetrating sagacity, ability, and truthfulness which characterize this author's observations, would be inclined to doubt the fact which this note reveals, viz. that the *basalt* passes into the laterite, whether by transition through the wacke is not clearly stated; but as the hill of Beedur is capped with laterite, the wacke to which he alludes must be between it and the basalt. "Iron clay" was Voysey's name for laterite; and when we reflect on the intense blackness of the overlying basalt, especially that of Bombay, compared with that of any of the other trappean effusions, and remember that in its course to the surface it must have passed through or between the great beds of siderocriste (spicular iron ore), of the gneiss, and other metamorphic strata abounding in oxidulated iron ore and manganese; and that circumstances which were not present when the former trappean effusions were passing through them might have caused the overlying basalt to have brought away a much larger portion of these minerals than any other effusion which preceded it, we shall not be altogether at a loss to account for the quantity of iron ore and manganese in the overlying basalt, and its tendency in particular to pass into laterite, where these minerals have become aggregated and exposed.

As it is the overlying basalt which passes into the laterite, the latter must be of the same geological age as the former; and as we have come to the conclusion that the great trappean mountains of the Western Ghâts were not elevated until this was ejected, the laterite must belong to some of the latest of the trappean effusions.

From what has been stated of this formation, it must also follow that it may rest on other rocks which are older than itself, besides those of the trappean system, which is the case. Again, the percolation of water through a rock so highly impregnated with iron as the laterite, might induce a similar change in the one immediately below it, which also appears to be the case, while the *débris* of the former, descending to the valleys, or accumulating on the sea coast, may form secondary laterites. Hence it becomes necessary to find out some specific character for the laterite overlying the trappean effusions; and this seems to be the absence of all grit, gravel, and the fragments of foreign rocks. This, however, will not be sufficient when the basalt giving rise to

the laterite may have formed a breccia with the rock through which it has passed, as in the granite hills of Ganjam in Cuttack (Sterling); but its local connections will then serve to explain the anomaly.

There are yet other instances in which laterite may be found, to which I will now briefly allude.

On the plateau of the Neilgherries, which is not without its dikes of trappean rock, viz. basalt, Benza states that there is 40 feet of lithomargic clay of a yellow-red colour, streaked with red and yellow beneath, formed from the decomposing surface of the sienitic and hornblendic rocks on which it rests; the felspar and hornblende going first, and then the quartz, in a friable condition; while lateritic conglomerates, too, of *rounded* pebbles, exist on each side of the Moyar river.

Again, in sinking a shaft in the vicinity of Bangalore, which is 3,000 feet above the level of the sea, Lieutenant Baird Smith, at 2 feet below the surface, came to variegated lithomargic earth, which at 15 feet began to get slightly more tenacious, and present felspar in the form of a white earth. This lasted till the shaft reached 20 feet, when the decomposed rock began to assume its real form, and at 22 feet proved to be a pegmatite.

On the opposite side of the raised land of the south of the peninsula, at the Bisley pass, it is stated by Newbold that sectile laterite overlies gneiss, which is veined with granite; and the Rev. Mr. Everest has stated that at Bancureh, on the road from Calcutta to Benares, granite is seen to be decomposing "into sand and grit, in which are imbedded masses of a quartzose reddish brown slaggy-looking ironstone," the hollows of which are numerous, irregular, and mammillated inside, and which he considers to have arisen from the decomposition of the granitic rocks, which, in two or three places, present veins of it cutting through them.

So that there are various kinds of lateritic rocks and beds, but they must not be confounded with the laterite which caps the trappean mountains, or forms the upper part of the overlying basalt in other places.

IX.

Intertrappean Lacustrine Formation. (H. J. C.)

This name is derived from its position in the trappean effusions, where it has been chiefly noticed. No doubt it exists or has existed on other rocks, but it is only in one instance that this has been satisfactorily demonstrated.

It has now been found almost throughout India in connection with the trappean rocks, that is, a lacustrine formation exists under the columnar basalt of Cutch, of Malwa, on the Rajmahal hills, remnants

on the isolated hills of Medcondah in the Hyderabad country, in the neighbourhood of Nagpore, in the Gwailghur hills, the Sichel hills, and in the island of Bombay.

Its position appears to be under the overlying basalt, and resting on amygdaloid, which, being a subsequent effusion, has separated it from the rock on which it was originally deposited.

It consists of argillaceous and argillo-calcareous shale, more or less indurated, chertified, or rendered jaspideous by heat, and from an inch to 40 feet in thickness; and in some places of limestone. Vegetable and animal remains abound in it, as will be described hereafter.

Voysey appears to have been the first who noticed this formation. He found, in 1819, fossil shells belonging to it 2,000 feet above the level of the sea, on the summit of the hills of Medcondah mentioned, which consists of trappean rocks resting on granite, about one hundred and fifty miles due east of Beedur, and therefore the same distance from the eastern border of the great trappean district. He afterwards saw it in the Gwailghur hills, *in situ*, and gave a descriptive section of it, from which the following from above downwards has been compiled:—

	Ft.
Nodular basalt, or wacken	10
Earthy clay, stratified, of different degrees of induration, containing flattened shells of the genus conus or voluta	2
Wacken, or indurated clay (almost always amygdaloidal)	15

Coulthard and Dr. Spry afterwards gave the following sections respectively, of the trappean effusions at Saugor in Central India, which also appear to include this formation. The former of a "swell of trap," the latter of a "well":—

Section of the "Swell of Trap." (Coulthard.)

	Ft.	In.
"Rubbish and soil	1	6
Indurated wacken, in angular pieces of uniform arrangement	10	6
Wacken changed into a species of puzzalama	1	0
A thin black streak (rather remarkable), a vegetable deposit	0	3½
A white hard earthy limestone, sometimes effervescing weakly with acid, sometimes not at all, with small yellow specks of calcareous spar	23	0
Wacken, with fibrous carbonate of lime, and ditto in veins with calcedony	7	0
An amygdaloid wacken, similar to the toadstone of England	6	0
	49	3½"

In allusion to the "Travertin" mentioned in this section, Coulthard states:—"But to the trap, not to the sandstone, belongs a hard white, earthy limestone, harsh and gritty to the feel on the fracture,

and in which, rather sparingly, are imbedded small round particles of calcareous spar, of a yellow colour. It belongs to the trap, and is, moreover, ever attendant upon it, throughout the range."

Section of the "Well." (Spry.)

	Ft.
Surface soil	3
Soft basalt	2½
Hard basalt	7
Soft basalt	1½
Wacken, with nodules of limestone	3
Travertin, with imbedded shells	1½
Coarse siliceous grit	2
Hard basalt	—"

The Society's museum now abounds in beautiful specimens of shells and other organic remains from this formation at Saugor, which have been presented by Dr. Spilsbury and Captain W. T. Nicolls. The latter (P.MS.) confirms Dr. Spry's observations, with a little difference, and gives as a section 20 feet from the "well":—regur; columnar basalt; brown or chocolate fine clay, breaking with a conchoidal fracture, and imbedding shells (*Physa*), separate and in blocks of nodular limestone; tuffaceous nodular limestone, mottled red; and fine red clay again, resting on "volcanic indurated clay?)";—while, about 150 yards from this, the regur rests on chalky limestone which contains "*Physa Prinsepii*," and overlies blue or red clay, containing small quartziferous cavities.*

The next notice we have of this formation is that by Malcolmson, who saw it and its fragments in several places, but particularly in a "narrow band" at the pass of the Sichel hills, near Nirmul, projecting from the escarpment of a steep mountain composed of "nodular basalt, and capped by a stratified rock, which also appeared to be basalt. And at Hutnoor, a little further north, he observed a bed of it 12 feet thick, resting on reddish granite, also capped by basalt. Here it chiefly consisted of stratified limestone, richly charged with bivalve shells (*Unio Deccanensis*).

* From the specimens of this limestone which Captain Nicolls presented to the Museum of the Asiatic Society at Bombay we learn that it is more or less argillaceous, and therefore in some parts converted into white chert by heat: that in others it is more pure and there rendered grey and saccharoid; that in others it is chalky; in others forms the chief part of a conglomerate consisting of semi-rounded pieces of red sandstone (with *Physa Prinsepii*), but never any portions of trap that I have seen. It is always coarse, earthy, and massive, not thin and laminated like the lithographic limestone of the Oolitic Series, through frequently dendritic. So much does it seem to be a part of the thin limestone formation resting on "red clays" and overlying the sandstone of Bundelkhund close by, that Captain Coulthard, as before noticed (p. 227), has expressed the hope that its continuity may one day be established.

From the shells and other organic remains which Malcolmson collected from this formation, the following descriptions have been given by Mr. J. de C. Sowerby :—

" *Chara Malcolmsonii.*—Oblong, spheroidal, with 10 ribs; three of the ribs are produced at the apex.

" This capsule is composed of 5 tubes, each of which is curled twice round. The figures represent a cast of the interior, the tubes being split down, and the outer halves broken away, and left in the chert. The specimens are silicified, and constitute almost the entire mass of the rock, in which they occur associated with *Physæ* and *Paludinæ.*

" *Cypris cylindrica.*—Twice as wide as long, almost cylindrical ; front very slightly concave ; the outer surface, which is very rarely obtained, is punctured.

" *Cypris subglobosa.*—Subglobose, triangular, inflated ; front concave.

" The outer surface of this crustacean is punctured, as in *C. cylindrica.*

" Both species occur abundantly in grey chert, with the *Unio Deccanensis* and other shells, and in various specimens of chert and indurated clay, containing *Gyrogonites, Paludinæ, Physæ,* and *Limneæ,* from the Sichel hills. The fossils are converted into calcedony.

" *Unio Deccanensis.*—Transversely oblong, rather compressed ; margin internally waved ; shell very thick ; surface finely striated.* Fig. 6 is in limestone from the northern descent of the Sichel hills ; the others are in chert from Munnoor.

" This species has often a ridge, which bounds the posterior portion, and is variable in size and elevation. Fig. 9 is from a part of a group of many individuals of nearly one size, badly preserved in the same limestone as fig. 6 ; but as they are regularly oval, and do not show a waved margin, they may belong, as well as fig. 10, which is in grey chert from Munnoor, to a species distinct from *U. Deccanensis.* Some flattened specimens from this limestone are 2½ inches broad.

" *Unio tumida.*—Transversely obovate, smooth, gibbose ; posterior extremity rather pointed ; beaks near the anterior rounded extremity.

" The section of the two valves united is regularly heart-shaped. The shell is rather thin, and it has something of the contour of *Cyrena.* It occurs in the same limestone with fig. 6, and the substance of the shell is replaced by calcareous spar, which cannot be broken so as to show the hinge.

" *Limnea subulata.*—Subulate, elongated, smooth ; spine equal in length to the body ; whorls five. In a nearly white, soft, siliceous stone, from Munnoor and Chicknee.

" *Physa Prinsepii.*— Ovate, rather elongated ; smooth ; spire short, body-whorl largest upwards. The largest are 2½ inches long, and upwards of an inch broad.

" *Melania quadrilineata.*—Subulate ; whorls about eight, with four striæ upon each ; aperture nearly round. Fig. 17, in grey limestone from the same locality as figs. 6 and 11.

" *Paludina Deccanensis.*—Short, conical, pointed, rounded at the base ; whorls 5 or 6, slightly convex ; aperture round."

Malcolmson also recognized shells of this formation in specimens of chert from the hills about the ruined city of Mandoo, in Malwa, already mentioned, which were presented to the Society by the late Lieutenant Blake.

* Hinge consisting of a single, large, compressed, pyramidal tooth in each valve ; the upper one resting in a fossa on the dorsal side of the lower one.

Next in order of occurrence, but by far the most ample and satisfactory description that has yet been given of this formation, is the following by the Rev. S. Hislop, which is extracted from his "Geology of the Nagpur State," to which I have before alluded.*

"*Mammalia or Reptilia* (?)—In addition to the part of a femur and the phalanx, before alluded to, as having been found at Junyápáni Chouki, which I am inclined to refer to this deposit, there have been discovered in it, about two miles west of Nagpur, a portion of a vertebral column, consisting, apparently, of eight vertebræ, and, not far from the same spot, a number of minute bones in a detached and very fragmentary state, belonging to all parts of the animal structure. Whether these remains of quadrupeds are exclusively of reptiles, or whether some of them may not also be mammalian, I do not possess knowledge enough to warrant my expressing an opinion; nor is it necessary that I should, seeing they are to be transmitted to London, and will soon be examined by those who are competent to the task. But I may mention that the teeth discovered among them indicate the former existence of saurians at the locality, one tooth being small and obtusely conical, with a barbed point, and another species,† which is very abundant, being comparatively flat and lancet-shaped, with the enamelled side of a darkish slate colour. To this class also may, perhaps, be referred a claw, half an inch long, brought to light at Telankhe*d*i, three miles west of Nagpur; while the stratum at Machhagho*dá* has furnished the impression, apparently, of a fresh-water tortoise.

"*Fishes.*—Remains of this class are found at Tákli and Machhagho*dá*, but chiefly at Páhádsingha. They consist for the most part of scales, some of the Ganoid and others of the Cycloid orders. The Ganoidians are probably to be referred to the Lepidotoids, to which the spinous rays collected with the scales may have belonged. The alternate depressions and elevations, which radiate from the centre of the Cycloidian scales, are beautifully preserved; some have 12 of each, and others a smaller number. One specimen, as was pointed out to me by that well-known naturalist Dr. Jerdon, has constituted part of the lateral line, and still bears the tube through which the mucus flowed that anointed the surface of the body. But the most curious object that has been met with in this department is a piece of a roe found at Tákli, in the two lobes of which the ova that had been matured are calcedonised, while countless minute granules are seen lining the ovarian membrane.

* Here a paragraph has been omitted, as the substance of it is given at greater length by the author at p. 266.

† This I subsequently ascertained to be a bony Ganoid Scale; but the progress of discovery has brought to light several small striated teeth, while one very large specimen is serrated on both edges.—S. H.

"*Insects.*—The exuviæ of this class are more numerous than might have been anticipated. They are found only at Tákli, and are chiefly elytra of beetles, of which nine species have been discovered, seven having rewarded the investigations of Mr. Hunter. Some are allied to the Buprestidæ,* another, in the opinion of its accomplished discoverer, is connected with the (soft-bodied) Heteromera, while two tuberculated elytra may possibly have belonged to some other family of the same tribe. In one of the fruits, to be mentioned below, there was found a hollow tube, binding together several of the surrounding seeds, and absorbing the juice of their enveloping pulp: this was, perhaps, the work of some one of the Dipterous order; and on a piece of silicified wood, which at the period of its deposition must have been considerably decayed, there was discovered a large number of little round opaque bodies, regularly arranged in a hollow. Can these have been the eggs of one of the Lepidoptera?

"*Crustacea.*—Of this class no order occurs except the Entomostraca, comprising the genus Cypris, with six species, all new, so far as I am aware; and a very interesting genus, which I am disposed to consider allied to *Lynceus* or *Daphnia*.

"*Mollusca.*—These are very numerous, consisting of *Melania quadrilineata* (Sowerby), and perhaps another species of the same genus not described; *Paludina Deccanensis* (Sow.), and 8 species not named; 4 species of *Valvata*, new; of *Limneæ* besides the *subulata* (Sow.) 5 new species; of *Physa* in addition to the *Prinsepii* (Sow.) 4 or 5 new forms, that may constitute as many species; of *Bulimus* 2 new species† with 12 other species that may be referable to the same genus; *Succinea* 1 species, and *Unio Deccanensis*. Most of the Paludinæ have been found at Tákli, along with the two well-marked species of Bulimus. Telankhe*d*i has supplied all the Limneæ, the doubtful Bulimi, which in many cases retain a stripe of colour on the shell, and the single species of *Succinea*, of which only one specimen has been met with. One species of *Valvata*, with a pretty striated spire, most frequently truncated, is found exclusively at Tákli. Another, also striated and conoid, leaves its impressions abundantly on the rock around Nagpur. Two without striæ occur at Machhagho*dá*, one carinated above, and sometimes conical, and at other times oblong-conical, and the other discoidal, and so minute as scarcely to be visible by the naked eye. *Physa* is the genus most extensively diffused, having been collected in all places where the deposit is fossiliferous. Besides the *P. Prinsepii* (Sow.) there is one new form found at Telankhe*d*i, which presents obvious specific differences; and there are several others varying from both of these, but by such gradual changes,

* *Curculionidæ.*—S. H.

† See note †, p. 263.

that under a sense of incompetency, I have sent them all to London for determination. The only remaining shell that has fallen in our way is *Unio Deccanensis* (Sow.), which was obtained by Mr. Hunter at Chikni, the locality pointed out by Malcolmson, which is the only locality for it that I as yet know of within the territory of Nagpur. The specimens of it that occur there are far from good, when compared with those kindly sent me from the neighbourhood of Elichpur by Dr. Bradley. That able and zealous geologist has also furnished me with excellent specimens of *Physa*, the forms of which agree with those common in the vicinity of Nagpur.

" We pass now to the vegetable kingdom, the specimens of which from the fresh-water formation are both rare and varied. They may be classed under the heads of fruits and seeds, leaves, roots, and wood.

" *Fruits and Seeds.*—Of these there are about 50 species. The order of the Exogenous sub-kingdom, that has most representatives, is the *Leguminosæ*, there being 4 species very obvious, viz. two *Hedysareæ*, and other two, including a *Cassia* of the more regular flowered division of the order. Under the same head may be arranged what appears to be a *Faboidea* of Bowerbank, a double-seeded fruit resembling the *Xylinoprionites* of the same author, and a three-seeded one, occurring sometimes with two seed-vessels, and at other times with three, which may have been a *Hedysarea*. The most abundant order of Endogens is *Aroideæ ?*, of which there are two genera, with compound fruits, one with three-seeded ovaries, in size and outward appearance being exceedingly like a small pine-apple, and the other genus bearing a distant resemblance to a mulberry, having, however, the seeds in each vessel symmetrically disposed in sixes. This latter genus contains two species : one, that must have had a rich purple pulp, was upwards of an inch in length, and half an inch in breadth ; and the other extended to 2 inches long, with a breadth not exceeding $\frac{1}{8}$ of an inch. Next to the *Aroideæ ?* the most interesting Endogens are *Palms*, of which there seem to be two genera, one a *Nipadites* (Bow.), and the other one a transparent piece of calcedony, whose place in the order cannot exactly be assigned. For the latter rare specimen, as well as for the larger mulberry-like aroid fruit, and many other fruits and seeds, we are indebted to Captain Wapshare, whose co-operation in this field has proved of the highest value to Indian palæontology. The fruits above specified, in common with those not mentioned, are almost all found at Tákli. The only exceptions worthy of notice are one of the *Hedysareæ*, which was laid open in a stone from Machhaghodá; separate ovaries of the larger six-seeded aroid, which are found along with fish-scales at Pahadsingha, and the *Chara Malcolmsonii*, which is met with, though not abundantly, wherever the deposit contains organic remains.

" *Leaves.*—Of these there are 12 kinds, seven of which are Exogenous. In some of these the secondary veins strike off from the primary at a very acute angle, and in others not so acute, while in one of orbicular shape they radiate from a central point like the leaf of *Hydrocotyle.* The Endogenous leaves are five in number, some of which possess a considerable similarity to those found in the Bombay strata, and figured in plate viii. of the Journal of the Bombay Asiatic Society for July 1852. All these have been obtained at Tákli, as also the roots.

" *Roots.*—These amount to five in all, none of which are much above an inch in length. The most conspicuous forms among them are those that are somewhat like a cocoon, marked by the scars of sheathing bracts. Of such tubers there seem to be three, differing in certain respects from each other, and agreeing in number with the three aroid plants, with which they are found invariably in juxtaposition. The similarity of one root in all but the size to that given in plate vii. fig. 1 of the able paper just referred to cannot fail to appear on the most cursory examination, and may serve to fix the place of the latter in the vegetable kingdom, as well as create the hope of finding near Bombay some aroid fruit which it has produced.

" *Wood.*—There seem to be three kinds of Exogens and two of Endogens. In some cases the former retain their bark, while the latter, as has been observed in other Indian localities, occasionally display their aërial roots. Specimens of wood are common in almost all fossiliferous parts of the territory.

" From a review of the whole fossil contents of this formation, the inference to be derived appears to be, that it cannot be more recent than the Eocene era. Bronn, in his Index, has set it down as of the same age with the Continental *Molasse ;* but the facts, that out of the many shells it has imbedded not one within my knowledge is specifically the same as any now existing, that there is almost an equal number of Ganoidian with Cycloidian scales, and that the fruits bear a remarkable resemblance to those found in the London clay of the Isle of Sheppey, in my humble opinion fully warrant the belief that it is one of the oldest of tertiaries. On the tempting theme of its extent throughout India I forbear to enter."

Lastly, we come to the lacustrine strata in the island of Bombay, which I examined in 1851, and described in No. XVI. of the Journal of the Bombay Asiatic Society ; see also p. 116.*

* The description of these strata as well as the infra-trappean deposit at Rajamundry which follows it, has been introduced here, but it will be seen by a foot-note further on, that the former and probably the latter also should be with the Eocene Group, thus leaving the Intertrappean Formation of the Deccan for the present with the Rajmahal Formations.

These, which lie under 50 feet of black, stratified basalt, and rest on intruded amygdaloid, like the foregoing, consist entirely of argillaceous shales, which superiorly, where they approach the basalt, are of a light brown colour, and inferiorly, where they are intruded by amygdaloid, of a dirty green or blackish colour. They are laminate in structure, and homogeneous in composition, where they have not been altered by heat; the fossils even have all become argillaceous; and although here and there may be seen a coarse, granular, and apparently heterogeneous stratum, lying between others of extremely fine texture, still the material of which that also is composed is soft, sectile, and argillaceous. It is only where these strata have been exposed to heat that they have become altered, and their fossils and every other part of them have passed from an argillaceous into a cherty or jaspideous state.

There is one exception, however, which is of much importance, viz. that here and there, also imbedded in these strata, are found fragments of unmistakeable *vesicular scoriæ.*

The deposit abounds in organic remains throughout, but they are much better preserved in the lower than in the upper part. Above the vegetable remains have been entirely decarbonized, while below they are still carboniferous, and in many instances present thin laminæ of sparkling grains of coal.

The superficial stratum, or last deposit, which is about three inches in thickness, is characterized by its siliceous composition and oolitic structure, being almost entirely composed of the casts of *Cyprides*, with a few small fragments of the stems of plants. Above this comes only two or three inches of argillaceous transitional matter, which passes into the wacken of the overlying decomposed basalt, and the wacken again into the compact basalt above all, through the nodular disintegration of the latter.

Fragments of reeds or stems of plants and their leaves, seeds, and numberless other fossils, apparently from the vegetable kingdom, the forms of which have become obliterated, abound in the light-coloured strata, the fragments particularly in layers, as if they had been deposited more at one time than another, perhaps by floods after heavy rain. About the middle, where the strata have not been wholly decarbonized, and the colour changes to dark green, cormiform roots abound, the remains of small frogs (*Rana pusilla*) in great numbers on black, carboniferous laminæ of shale, and of a fresh-water tortoise (*Testudo Leithii*). Dr. Leith, who found several specimens of the latter, also subsequently presented to the Society part of the lower extremities (the *tibiæ*) of a frog, which he computes to have been about three inches long, from the same formation. Below this comes the most carboniferous part of the series, which abounds in large pieces of dicotyledonous

woods, flat long ensiform leaves, and a number of seeds, seed-pods, and other remains belonging to the vegetable kingdom. This part is impregnated with a naphthous odour, and presents small deposits of sparkling coal throughout, in connection with the vegetable remains.

Besides the fossils mentioned, *Cyprides* abound in every part; a long species, *Cypris cylindrica*, perhaps, of the deposits on the eastern margin of the trappean district; another species not well characterized, and *C. semi-marginata*, which appears to be a new species. The elytra of insects, and impressions of shells like *Melania*, are also present, but the latter are too indistinct for description.

Calcareous spar abounds in the lower strata, where much of the shale effervesces when acid is applied to it; and in one part I found the portions of vesicular scoriæ to which I have alluded, the presence of which is important, because it seems to indicate that the trappean effusions had commenced before this lacustrine deposit had begun to be deposited.

As I have before stated, the lower part of this series has been found intruded by amygdaloid wherever it has yet been noticed, and therefore neither its whole extent, nor the rocks on which it was originally deposited, are yet known. Its strata, in a chertified and jaspideous condition appear, here and there, in all the trappean effusions of the island, except in the basalt, which overlies it; and the plains are strewed with their fragments, contorted and twisted into various shapes, from the almost melting heat to which they have been exposed.

For a more elaborate account of this formation in the island of Bombay, I must refer the reader to my paper on the geology of this island, p. 116, *antè*.

There is yet another instance to which we should direct our attention before we leave this part of the subject, where a similar deposit exists under basalt, in an insulated hill two hundred and fifty miles to the eastward of the great trappean district. I allude to that pointed out by General Cullen to Dr. Benza, in the Northern Circars. It is situated about five miles to the west of Puddapungulla, a village near Rajamundry, just above the delta of the Godavery, and consists of a bed of limestone, lying apparently in "wacke." Benza has stated that the limestone is white, and glimmering, from the sparry nature of the fossil shells which are in it, and that it breaks with a semi-conchoidal fracture. The shells consist of "oysters, unios, small melaniæ, &c." The hill is capped with basalt, decomposing in spheroids and concentric layers, and the "wacke" below the limestone is traversed by thick veins, and small ramifications of jasper, the whole apparently resting on sandstone conglomerate.

It is just possible that this may be a marine tertiary formation, as we

shall see hereafter; but its position in the "waeke" or decomposed basalt, and the resemblance at first sight of large unios to oysters, which led Malcolmson and Voysey to mistake the former for the latter, and may also have misled Benza, makes it very like a deposit of the inter-trappean lacustrine formation.* The presence of sandstone conglomerate below all may also be useful to remember, as this may be the diamond conglomerate.†

* As further instances of the mistakes which have been made in the nomenclature of these fresh-water shells, the following may be cited :—Thus, Voysey considered those of the Gwailghur hills to belong to "conus and voluta"; those which he found in calcedonies among the *débris* of trappean rocks in the bed of a river at Daigloor, near Bhuktapore, "buccinum, helix, and turritella"; while Dangerfield considered those which he saw in Malwa to belong to "buccinum," and a "species of mussel." There can be very little doubt now, but that all these were either *Physa Prinsepii* or *Unio*, or other shells of the intertrappean lacustrine formation.

† In connexion with the Lacustrine Strata of the Island of Bombay and those near Rajamundry above mentioned, I should here notice a recent discovery of sedimentary deposits similarly situated, that is, under laterite, at Rutnagherry, a town on the western coast of India about one hundred and fourteen miles south of Bombay.

Dr. De Crespigny, to whom we are indebted for this important addition to our knowledge of the inter-trappean formations, states, in his note dated the 16th July 1856, that in a quarry near Rutnagherry, where he is residing, beds of lignite are found, and that "1,000 yards further in-land a well was sunk through the laterite which gave the following section" :—

	Ft.
"Soil and detrital conglomerate, a few feet.	
Laterite (soft below)	35
Compact iron-stone	1½
Lignite } Blue clay }	27
Water, yellow gravel.	
Trap."	

As the existence of these strata was casually noticed by Dr. De Crespigny and I did not see his observations until the rains had commenced; he had not the means, when I wrote to him on the subject, of sending me more than the above section with specimens, but he will resume his researches as soon as the subsidence of the water in the quarries and wells about Rutnagherry takes place; meanwhile there is sufficient in this section and the specimens to attach great interest to the subject.

In his note, he further observes :—"the lignite underlies the solid laterite, which you and Voysey declare to be of volcanic origin." This is his reply to the question whether it was a laterite of detritus, or what I have termed genuine laterite, viz. that which contains no foreign material and appears to be a mere decomposition of trap or basalt; because if this 35 feet of laterite be the remains of a trappean effusion, then these strata, so far as this goes, are most assuredly similarly situated to the Lacustrine Strata of the island of Bombay.

But to return to the specimens. I learn from these that this formation consists above of an argillaceous, gravelly deposit, speckled white and grey, in which are imbedded black lignite, mineral resin, and pyrites, and below this fine, blue, plastic clay; all of which are identical with the lignite, mineral resin, pyrites, and blue clay of the beds which underlie detrital laterite on the coast of Travancore; but the speckled argillaceous deposit, in which the lignite is imbedded, resembles the Intertrappean Lacustrine strata of Bombay, in which fossil wood is also found, but coaly or argilised.

No shells have yet been found, so that whether these deposits took place in salt or in fresh-water is not yet known; but the pieces of lignite are much rounded by attrition, and there are

We now come to the evidence that has been communicated of the existence of this formation on other rocks besides the trappean effusions, and this is very scanty indeed. No one can doubt but that further exploration alone is required to prove its presence in many places; but as yet there is but a solitary instance on record to substantiate the fact, and this I have already mentioned, viz. the existence of a series of limestone strata, 12 feet in thickness, richly charged with *Unio Deccanensis*, which Malcolmson saw resting on "reddish granite" capped by basalt, at Hutnoor, in the Muklegandy pass a little north of Nirmul.

Voysey, however. in his last journey, viz. that from Nagpore to Calcutta, came upon a bed of "oyster shells," which I think must have been unios, in limestone, at Dooroog, about one hundred and twenty miles east of Nagpore; and of this he states :—"In my vicinity are numerous excavations of considerable dimensions, for the purpose of making tanks—the bottoms about 50 or 60 feet below the surface. In one SE. of the town, there is a thick layer of limestone, of a reddish colour, which at first appears to be a kind of breccia, or pudding-stone, but on narrow inspection, it is evident that the whole consists of a thick bed of oyster-shells, which have been in some cases completely petrified, and changed into a compact limestone; and in others, on fracture, conchoidal laminæ are very distinct. Perhaps it will be difficult to convince some persons that these are really petrified oyster-shells, but I have not the slightest doubt that an experienced geologist will at once admit the fact. It remains to be ascertained whether the rock has a bituminous or ammoniacal smell before the blow-pipe. They appear to differ very little from the shells at Miaglah Condee, except that in this instance they are entire, whereas in the former place they are broken; here, also, they appear to have been compressed. The bed extends beneath the diluvial soil as far as the bed of the river, where there are a few scattered blocks." He found it again at Ryepore, some miles beyond Dooroog, in the bed of the Karoonuddi, and in the wells dug by Colonel Agnew and Captain Hunter, which are 50 feet deep,—resting therein on clay slate; and in a quarry at the same place where the latter passed into sandstone; also some pieces of the same shelly limestone on his way to Chandcoory, and on to Bhainsa. At Lowun he mentions "black slaty limestone" underlying the diluvial soil, and that it is be found on the river Mahanuddi; and at Beliaghur clay-slate succeeded by reddish sandstone, where he makes the remark on the geological antiquity of

carpels and seeds, apparently of some large tree, among the specimens, so perfect, that if the forms of the vegetable remains generally be so well preserved as these, there will not be much difficulty in determining the *flora* of this formation. To its probable geological age, as well as that of the Bombay strata and those of Rajamundry, we shall come by-and-bye.

these rocks already quoted. This sandstone extended on to Jora Devi; and in the Silman pass, a little beyond, he saw "sandstone conglomerate immediately followed by the clay-slate and shelly limestone." At Bilaipore a breccia of the clay-slate in a paste of quartz, "very few of the masses of which seemed much rounded by attrition." Then the usual sandstone, followed by the calcareous clay-slate. "At Laindurrah sandstone appeared to be the prevailing rock, and at the top of the pass the calcareous clay-slate." In the beds of the nullas, clay-slate "under the sandstone, which is, generally speaking, the lowermost rock." At Cordeonah, sandstone, beneath which is clay-slate. Then, after passing over sandstone conglomerate, he states :—"I came on large-bedded masses of granite, but did not see their junction with the conglomerate, on account of the diluvial soil ; granite continued on to Sumbulpore, then gneiss, and a little argillaceous limestone, after which metamorphic rocks and granite all the way to the Subunreeka." While at Sumbulpore, he visited the diamond washings in the Mahanuddi. The diamonds were sought for in the sand and gravel of the river, the latter consisting of pebbles of clay-slate, flinty slate, jasper, and jaspery ironstone of all sizes, from an inch to a foot in diameter.

At first it would appear useless to follow Voysey through this journey in the hope of identifying his bed of "oyster shells" in limestone with the intertrappean lacustrine formation, on account of no allusion having been made to the "shells at Miaglah Condee," from which he states "they appear to differ very little,"—in any other part of his journals. But when we observe the close resemblance, both in name and permutability of spelling that exists between "Miaglah Condee" and "Muklegandy," by which the pass leading into the valley of Berar from the Nizam's territories is called, and connect this with the fact that at Hutnoor, in this pass, Malcolmson saw the lacustrine limestone strata richly charged with what he then conceived to be shells of "*Ostrea* and *Cardia*," but which afterwards proved to be *Unio Deccanensis*, &c. resting on "reddish granite,"—that which seemed to be hopeless of explanation appears to be perfectly intelligible, and the identity in name and geological formation complete. When, also, we consider that Voysey did not recognize the lacustrine nature of these shells any better than Malcolmson; that the only bit wanting to complete his itineraries is that between Hyderabad and Nagpore; while Colonel Lambton's northernmost station in 1819 was Shivalingapah, near the south bank of the Godavery, not far from Nirmul, where the Muklegandy pass commences; and that in 1822 he had carried his triangulation across the valley of Berar to Ellichpore; there is every reason to believe, from the nature of the country, that he carried it through the Muklegandy pass, and that Voysey, who was attached to his survey,

had then plenty of opportunities, which he never allowed to escape him, of witnessing among the portions of the lacustrine formation which is here exposed in several places, the very limestone strata and its numerous *Unios* which Malcolmson himself saw in marching through this pass in 1835. But, as I have before stated, this part of Voysey's journal is unfortunately wanting, and the only place where he seems to allude to this locality, is in his last notes between Nagpore and Calcutta, where he mentions the place in question, "Miaglah Condee." Colonel Lambton died at Hingan Ghàt, on his way from Hyderabad to Nagpore in January 1823, and Voysey left the latter place or its vicinity for Calcutta in February 1824; but he states, in his "Report of the Geology of Hyderabad," that he had seen shells in the trap of Medcondah, and in the wacken of Shivalingapah; and in his account of those which he saw in the Gwailghur hills, in April 1823, he mentions that he communicated in June 1819, as has before been stated, in a report to the Marquis of Hastings, the fact of their existence in Medcondah, though we cannot trace him in his journals to either Medcondah or Shivalingapah. Again, it is evident, from the concluding part of his paper on those of Gwailghur, that he had seen fresh-water shells of the intertrappean lacustrine formation in more places than he has mentioned.

Besides, who has yet seen anything like "beds of oyster shells" in limestone or calcareous strata in the interior of India, and what indications are there of such a deposit existing there in the formations hitherto described? None that I can see. Thus everything tends to the conclusion that Voysey's limestone strata with oyster-shells at Dooroog, and the other places mentioned on his way to Sumbulpore, were parts of the deposit under consideration.*†

We shall have to recur to this subject again by-and-bye, but in the meanwhile let us direct our attention to the intertrappean deposits of the lacustrine formation in Cutch, and to the coal formation resting on the trap of the Rajmahal hills in Bengal.

* *Miaglah Condee* and *Muklegandy* are almost undoubtedly the adjectival forms of مغل *Mughul*, viz. مغلي *Mughuli*, or مغليه *Mughuliyu*; and *Condee* or *Gandy* that of *Condah*, a common Telingi terminal affix to places in this part of India; while the Hyderabad country is called by the Mussulmans *Mughlui*; and then *Miaglah Condee* and *Muklegandy* pass would mean the *Mughli Condi* pass (pronouncing the vowels as in Italian), or the passage from the valley of Berar into the *Mughlui* country. At the same time, it is not improbable that the third stroke of the *m* in the MS. has been mistaken for an *i* by the compositor, and that this has led to the strange spelling, "*Miaglah*," which has such an uncommon orthography that it seems that it must be incorrect. I am not an advocate for this kind of reasoning in scientific inquiry, and therefore only add these observations for what the reader may think them worth, in connection with the facts above stated.

† This question, so far as Dooroog is concerned, has since been decided by the Rev. Mr. Hislop in quite another way; the "beds of oyster shells" being nothing more than organic appearances caused by "the peculiar concretionary structure of the rock;" see *antè*, p. 249.

Of the former, Colonel Grant only describes one instance, viz. that at the village of Wurrowsow, on the SW. flank of the Charwar range, of which he gives the following section:—

	Ft.	In.
"Columnar basalt	20	0
Rubbly basalt	0	6
Crystalline travertin	1	6
Friable calcareous stone	0	3
Travertin	0	6
Friable iron clay	0	3
Solid basalt	1	6
Friable basalt	——	"

In this section we have the superficial basalt becoming rubbly or nodular as it approaches the travertin, and that below, as is commonly the case, apparently passing into the latter through a transitional ferruginous clay. No organic remains were seen in the travertin.

The following description of the coal strata in the Rajmahal hills, which has been given by Dr. M'Clelland, is provisionally placed here, because it rests on the trappean effusions:—

"Rajmahal Coal Formation."

"This consists of thin beds of coal, shale, clay-ironstone, and sandstone, forming the upper beds of coal formation, resting on enormous beds of secondary trap.*

"These appearances were examined with great care at Mussinia, Dhomaripore, Taldee, Kottycoon, and Dubrajpore; and found to be everywhere so much alike as to leave it in considerable doubt whether they do not all refer to one and the same set of strata, appearing at each of the various points alluded to.

"The district in which these appearances occur is mountainous, the levels varying from 50 to 1,500 feet above the sea. It is reasonable, therefore to conclude, that if good workable beds of coal existed, they would be somewhere brought to view amidst so much local disturbance.

* Mr. Oldham states (p. 268, vol. xxiii. Journ. As. Soc. Bengal) respecting these beds: "The rocks associated with the coal rest invariably on the old gneissose and primary schist rocks, for the most part dipping at low angles or nearly horizontal, and are in all cases covered up (and not underlaid) by the great overflowing sheets of trappean rocks, which form the larger portion of the hill district," and below, in a foot-note, he himself alludes to this discrepancy with Dr. M'Clelland's statement.

If such be the case then this coal formation should be transferred to the Oolitic Series; but as it cannot well be separated from the following one, termed by Dr. M'Clelland "Inferior Oolite," this must also undergo the same transposition, which will leave the "Intertrappean Lacustrine Formation" of the Deccan by itself, unless this also prove to be of Oolitic age, as suggested; when the other intertrappean formations being carried to the Eocene Period the necessity of having a separate division for these formations will no longer exist.

"The higher ridges of these mountains consist of scoriform masses of red earthy vesicular conglomerate (laterite), containing angular and other fragments of altered coal measure shales, ferruginous and micaceous sandstone, imbedded in a semi-vitrified and vesicular matrix. These ridges are without any signs of stratification, except where detached masses of altered coal formation occur; while the upper portion of their declivities, as well as all the lower and intermediate ridges, are composed either entirely of amygdaloid trap, containing zeolites and calcedony, or altered coal measure sandstone and shale, the latter passing into the small isolated patches of coal measures which are found in some of the narrow valleys and ravines already mentioned.

"These coal measures would appear to have been the object of repeated and fruitless attempts, on the part of coal finders, to discover workable seams.

"But such is the development of secondary trap throughout this district, that no hopes can be held out of any useful results from such trials.

"This remark is only intended to apply to that portion of the Rajmahal hills which has been examined by the survey, lying south of Patchwary, or between that place and Bullcah Narainpore. It applies, however, to all those localities in which coal has been stated to exist in the Rajmahal hills (vide Reports of the Coal Committee), except Hurra and Sielygully, which yet remain to be examined, together with that portion of the hills extending from Patchwary Pass northward to the Ganges."

The computed section of these coal strata gives about three times as much fine and coarse (more or less) micaceous sandstone and conglomerates, as bituminous shale;—carboniferous shale about one-fifth as much;—the coal strata very trifling, viz. 1 to 6 inches in thickness, and near the surface;—with altered sandstone and conglomerates at the bottom, followed by altered shale, each about 22 to 26 feet,—resting on amygdaloid.

One section, viz. that at Kottycoon, is of 100 feet, and the stratum of coal 2 inches; the other, viz. at Mussinia, 116 feet, and the stratum of coal 6 inches.

The coal lies between bituminous shales about 16 feet from the surface.

Of the coal measures at Kottycoon, Dr. M'Clelland states:—

"These thin coal measures rest in horizontal strata, on beds of hornblende slate (Ruttunpore Ghàt). They occupy a small space at the western foot of Dabrajpore or Umrah hill, the highest mountain in the district.

"The mountain consists of amygdaloidal trap, and semi-vitreous

earthy scoriæ, having conglomerates and shale of the coal formation resting on its sides in broken masses and outlines, everywhere altered, and invaded by amygdaloidal trap."

In speaking of the amygdaloid and common trap of the Rajmahal hills, he states :—

"Common jaspar of inferior quality also occurs, in beds connected with the clay ironstone of the altered coal measures, in the same locality."

Overlying the amygdaloid is his "common trap," which is avesicular, and of this he observes :—

"The higher ridges consist of scoriform unstratified masses of red earthy vesicular conglomerate, containing angular fragments of alternated coal measure shales, ferruginous and micaceous sandstones and conglomerates, imbedded in a semi-vitreous vesicular matrix."

Under the head of "Inferior Oolite" is then stated :—

"Resting on beds of overlying trap in the Rajmahal hills are certain greyish and bluish-white indurated clays, rendered slaty in places by the abundance of leaves of plants they contain. These clays have been altered by the contiguity of trap. They were originally stratified, but now exist in the form of hard, broken, and detached porcellanous masses."

The following vegetable impressions from this formation have been described by Dr. M'Clelland :—

"*Zamia Indica.*—Leaf long, and very slightly tapering; leaflets short, rhomboidal, oblique at the base; seven nerved, nerves crowded, and alternately terminating before they reach the apex of the leaflet.

"*Zamia Theobaldii.*—Leaflets alternate, oblong, obliquely accuminate.

"*Tæniopteris spatulata.*—Frond linear, 2 to 3 inches long, narrow at the base, becoming broader towards the apex, or sub-spatulate.

"*Obs.* This occurs very frequently.

"*Tæniopteris accuminata.*—Frond 2¼ inches long, linear-oblong, rounded at the base, accuminate towards the apex.

"*Obs.* This is of more rare occurrence.

"*Tæniopteris crenata.*—Frond linear, 2 or 3 inches long, narrow at the base, and rounded at the apex; margins laterally crenate.

"*Obs.* These, together with *T. spatulata*, are so common, that it is chiefly to them the slaty structure of the bed in which they occur is owing.

"*Poacites minor.*—From beds of bituminous shales at Mussinia. It is the same as [*P. minor*, M'Clell.] of the Burdwan fossils."

In the Rajmahal hills, then, there is a formation, which, in the nature of its strata, its thinness (100 feet), and its connection with the trappean effusions there, closely resembles the intertrappean lacustrine formation of Central and Western India. Yet its vegetable impressions, and the

Poacites of the bituminous shale at Mussinia being the same as that of the Burdwan coal strata, would seem to point out that it belonged to the Oolitic Series, and hence Dr. M'Clelland appears to have called it "Inferior Oolite," for I assume that as the "Rajmahal Coal Formation" and "Inferior Oolite" of M'Clelland both rest on the "trap" of the Rajmahal hills, they are parts of the same system, if not the same deposits. One of three things, then, is evident here:—either the first trappean effusions took place during the Oolitic period; or some of the species of plants of the Oolitic period continued to exist after its expiration; or (if by resting on the trap Dr. M'Clelland should mean adventitiously), these coal strata have been raised from the formation to which they belong, or from that on which they were originally deposited.

Pending the decision of these questions, I think the coal strata of the Rajmahal hills had better be provisionally classed with the Intertrappean Lacustrine Formation.

In recapitulation of the facts given under this head, which seem most deserving of our consideration, we find—

1*st.*—That, in addition to resting on the trappean rocks, the intertrappean lacustrine deposit has been seen by Malcolmson to rest on granite in the Muklegandy Pass.

2*nd.*—That in the neighbourhood of Saugor and Nagpore, where the trappean effusions become fringed out, they are attended by a distribution on the surface of fossils from the intertrappean lacustrine formation; and that these fossils in the Saugor district being situated in an intertrappean stratum of limestone which, at one part, comes into close proximity with a thin limestone formation overlying the sandstone of Bundelkhund, the latter may perhaps be found to be a continuation of the former, and, therefore, also to belong to the intertrappean formations.

3*rd.*—That there is a great similarity in position, and trappean disturbance and admixture, between the coal formation of the Rajmahal hills and the lacustrine formation in the island of Bombay; that the coal in the latter, too (which is described at p. 131), is not brown coal, such as we shall come to by-and-bye, in the deep blue clay deposits of the coast, which will also appear to come near its own age, nor lignite, such as we shall find in the more recent formations of the same locality, but a degree further advanced towards the old coal of the Carboniferous Series; also that we have, in the island of Bombay, these strata subsequently intruded by trappean rocks in the form of conglomerates and amygdaloids, just as described by Dr. M'Clelland in connection with the coal formation of the Rajmahal hills. What influence the heat from the overlying basalt and subsequent trappean effusions may have had in approximating the

carboniferous deposits in the lacustrine strata of Bombay to the state of old coal, I am ignorant.

4th.—That the strata of the intertrappean lacustrine formation have, in many instances, been lifted out of their original position, and sometimes so divided as to appear in thin strata, in differents part of the trappean effusions which have invaded or enveloped them. This is very well seen in the island of Bombay, where, in one place, a stratum one foot thick lies under 90 feet of trappite, and then comes 20 feet more of the same rock below it, after which follows volcanic breccia, containing portions of the other parts of the lacustrine strata. In Malcolmson's description of the Muklegandy Pass, he states that there are three terraces leading from the summit downwards into the valley of Berar. The summit of the pass is composed of basalt; and on descending to the first terrace, he found "fragments of a compact blue limestone, not to be distinguished from that of the diamond districts," the strata of which were much inclined and broken. Then, on descending to the second terrace, he found the white limestone strata charged with *Unio Deccanensis*, &c. already mentioned, lying on granite, and again overlaid by basalt. While we learn from Dr. M'Clelland's description of the coal formation on the Rajmahal hills, that this also rests on enormous masses of "secondary trap," and that it has been extensively broken up by subsequent effusions; also that there are porcellanous masses of indurated clays resting on the overlying trap of these hills, which contain fossils of the "Inferior Oolite." He further mentions, that in one part, the coal strata rest "horizontally on beds of hornblende slate."

5th.—Lastly, that the intertrappean lacustrine strata in Bombay contain straggling pieces of hollow vesicular scoriæ.

From these facts, then, we may deduce the following conclusions, viz. that some of the lacustrine deposits took place prior to the first trappean effusions; that in the island of Bombay the presence of scoriæ indicates that this deposit took place subsequently to some of them; that generally, these lacustrine deposits in the Deccan, where they are connected with the trappean effusions, lie under a capping of basalt, and that they have all more or less been raised from their original position and intercalated by amygdaloid.

X.

Volcanic Rocks.

Trappean System, 2nd Series. . { *Trappite.* / *Amygdaloid.* / *Volcanic Breccia.* }

The second series of trappean effusions includes all those which have taken place in India since the elevation of the Ghâts.

Subsequent to the breaking up of the trappean plains, and the upheaval of the stupendous masses which form not only the Western Ghàts, but all the ranges of mountains upon the great trappean district, a series of effusions appears to have been ejected between the elevated ridges of the old trappean tract, as well as in other parts at a distance from it, all of which now assume the form of low hills or plains, occupying a variable extent of surface.

In the island of Bombay they consist of trappite, amygdaloid, and volcanic breccia; and they are all characterised by enveloping more or less of the intertrappean lacustrine strata, or of other rocks. The same is the case with similar effusions on the Rajmahal hills. Malcolmson also states, that on the banks of the Pennaar he saw a breccia, formed of the "diamond sandstone" and a semi-vitrified rock, which he hesitated to refer to the trap family "until he had seen varieties of a red wacke," much resembling it, which constitutes part of the mountains in the island of Salsette; and Captain Meadows Taylor, in a private letter to me, accompanied by a sketch-map, points out the existence of large tracts of indurated trap-mud or clay, including blocks and nodules of basalt, which bounds the south-eastern border of the great trappean district between the Bhima and the Kistnah, and overlies in its outskirts the adjoining granitic rocks and limestone of the Oolitic Series. Many other instances of this effusion, no doubt, exist in other places, though they have not yet been mentioned.

Trappite.—The characters of this rock have already been given, and all that I have to add here is, that a bed of it exists in the island of Bombay, from 0 to 150 feet in thickness, the upper surface of which is tesselated in the manner of other rocks that have from a semi-fluid state become consolidated in contact with the atmosphere; while it envelopes long tracts of strata, which have been thus isolated by it from the intertrappean lacustrine formation. In one instance there are 90 feet of trappite above, and about 40 feet below a stratum of this formation, which is only from 1 to 2 feet in thickness. One ridge or dike of this trappite presents the peculiarity of being mottled with darker coloured portions than the rest of the rock, and these remaining almost intact while the lighter coloured part weathers away, causes it to assume the form of a conglomerate of bullet-like masses, of different sizes, from which I have termed it "Orbicular Diorite"; it should be called "Orbicular Trappite."

Amygdaloid.—This, formed of a trappitic base more or less aphanitic or amorphous, is chiefly characterised in Bombay by the presence of laumonite, calcspar, and quartz in its cavities. In some parts all three are present, in others they are alone, and are then most developed. It has invaded the lacustrine strata to a great extent, and broken them

up into masses, which now lie imbedded in its structure, or in the form of chert and jasper, twisted and contorted in all directions and strewed about its decomposing surface. In colour it varies from blue to fawn or brown. In the latter state it has been called "White Trap," and in the quarries where it is least vesicular, presents a prismatic, columnar structure, like that of the black basalt. In many parts it is impregnated with calcspar, which only becomes visible when its planes of crystallisation arrive at a position favourable for reflecting the rays of light towards the eye. In this state it appears to form spilite (Brongniart). The light colour, however, disappears on descending, and after a few feet passes into blue, when the rock approaches the form of trappite, but appears to be more compact and less crystalline. The calcspar is sometimes in veins, sometimes in small crystalline masses forming part of the rock like the other ingredients, and sometimes diffused throughout its substance, only becoming visible in the way above stated; in this form it very much resembles diffused glassy felspar. The amygdaloid is not raised into hills, like the trappite, nor have I distinctly seen it overlying the latter, though it appears to be a subsequent effusion.

Volcanic Breccia.—This, which in the islands of Bombay and Salsette presents all the characters that heat, water, and decomposition can give to an effusion of the kind, is composed of angular fragments of sandstone and sandstone conglomerate, argillaceous shale, amygdaloid, basalt, diorite, and granitic rocks, to which may be added fragments of the lacustrine formation; imbedded in a compact, jaspideous, granular, or cavernous, arenaceo-argillaceous, loose base; solid, unstratified, sometimes pseudo-prismatic; of a red, blue, grey, or black colour; passing, in decomposition, from the jaspideous, black, homogeneous form into a fine red clay; and from the loose, arenaceo-argillaceous, red state into a sub-granular, red, sandy earth; in both instances losing all traces of its original composition. The reason of its possessing all these characters is that it exists in the island of Bombay in the state of a breccia, and in that of a black jaspideous basaltic rock, with all the intermediate varieties and decompositions peculiar to either.

A person may walk from the red hills, where it is in a loose, friable, lateritic state, to the black hills, where it is in a jaspideous one, passing over a plain of it, which, gradually becoming more and more compact, at length assumes a darker colour, and finally, losing all heterogeneous composition, ends in a black, jaspideous, homogeneous mass. On his way, too, he will pass over parts of the surface where there is the polygonal division common to rocks which have been in a semi-fluid state, and here the fragments of which the rock is composed are most evident and striking; while the same effusion, in some parts under the trappitic

crust, where it has been continually exposed to moisture, is throughout of a soft, cheesy consistence. The friable sectile state of this breccia, where it forms the red hills, is the only part where the fragments of the rocks contained in it retain any trace of their original structure and appearance, and even here the whole has undergone such alteration, that, in hardness, all parts yield equally to the cutting instruments which are used to fashion it into blocks for architectural purposes. Still the structure of a conglomerate may be detected in many of these fragments, though this hardly amounts to more than the rounded cavities and black ferruginous shells of the gravelly pebbles which they formerly contained; while the various colours of the fragments, viz. deep black, red, chocolate, brick-red, violet, lilac, grey, and variegated with specks, spots, or streaks of one in a base of the other, together with a zonular arrangement in some, bear such a striking resemblance to the colours of the fine argillaceous sandstones and their nodules of the Oolitic Series, that no doubt, hardly, can be entertained of their having belonged to the latter.

At first I thought they must have come from the intertrappean lacustrine formation, for I knew little then of the characters of the sandstones and shales of the Oolitic Series, or how they were situated with respect to the trappean effusions. But since I began to reflect on the extent of the volcanic breccia in the neighbourhood of Bombay, and remembered that the whole of the trappitic and basaltic crusts of the island are most probably underlaid by it; that it forms all the hills on the north-eastern part of the island, some of which are 130 feet high; that it also forms a great part of the mountains in the island of Salsette, and extends to its northern extremity, making in all a tract north and south of twenty-eight miles, and probably a great deal longer, I have naturally come to the conclusion that the lacustrine formation could not have supplied all the fragments in this great mass, and that their origin must be sought from some other source. I therefore examined several of them carefully, and found what has been mentioned, but the subject deserves a much more extended investigation than I have been able to give it.

The lateritic character of this effusion, where it forms the red hills, is very striking, and a full description of it and of the effusion generally will be found in my "Geology of the Island of Bombay." Suffice it here to add, that the distinctive character of this volcanic breccia from the genuine laterite, consists in the presence of fragments of other rocks in it, as well as its position.

Diking these red hills will be found a similar effusion, of a much lighter colour; so much so, that when fresh from wells which are being sunk in it, it serves for white-washing. This, on examination, appears to be a kind of trappitic kaolin, for if the white decomposing powder be brushed off in water, a gritty mass will remain, presenting the

greenish tint and general appearance of trappite. This effusion has not only veined and burst through the trappitic crust in many places, but in one part it overlies the crust of one of the trappitic ridges, which is 100 feet high, and there appears as a white amygdaloid, the cavities of which are filled or lined with siliceous minerals only, viz. quartz, calcedony, or agate.

Many of these cavities or geodes are half as large as a man's head, and contain large crystals of colourless or amethystine quartz.

Lastly, there is an effusion, which has all the appearance of an old pisolitic pumite: it is harsh to the touch, breaks with a rough fracture, and presents the short-cut fibrous structure peculiar to pumite conglomerate. In it, too, are rounded pebbles of the so-called white trap to which I have before alluded, with its vesicular cavities filled with decomposed laumonite and general calcareous impregnation, besides fragments of other rocks belonging to the trappean effusions. I have only seen a few specimens of this, of a blue colour, which were picked up by Dr. Leith in the island of Salsette, where they were mending the roads with it. This is decidedly the nearest approach to modern volcanic effusions that has come under my notice in the neighbourhood of the island of Bombay.

There is a fac-simile of it in a stratum at Aden some way up the base of the mountain, in Back Bay, but there it still retains the lightness, freshness, and looseness of structure indicative of more recent origin, while that of Salsette is heavy and consolidated, and, therefore, more nearly approaches trachyte.

All these effusions in the island of Bombay appear to have undergone elevation since they were ejected; they have a more or less sloping and a scarped side, the former presenting towards the east, the latter to the west.

The fragments of the sedimentary rocks in the volcanic breccias of the Rajmahal hills, and those in the trappean effusion on the Pennaar mentioned by Malcolmson, all appear to retain much more of their original structure, elementary composition, and appearance, than those in the volcanic breccia of Bombay; yet a large angular fragment of a granitic rock, found by Dr. Leith in the transitional part of the volcanic breccia of the black jaspideous hills, still retains its original whiteness, and vindicates its right to a place among rocks, which, however near the surface of the great trappean district in the island of Bombay, are not found *on* it for hundreds of miles all round.

In his sketch of the geology of the "Bombay Islands" Dr. Thomson seems to have applied the name of porphyry to the volcanic breccia; but I have seen none of it which merits this appellation, though I should mention, that on comparing some blocks of red porphyry that were

brought from Jiddah with the decomposed red breccia of the hills at the north-eastern extremity of the island of Bombay, and of others in Salsette, the two appear to be identical, but for the decomposition of the latter. The compact red paste, throughout which are disseminated small, white, well-defined crystals of felspar, with here and there fragments of other rocks, in the Arabian porphyry (*Porphyre antique*, Brongniart), appear to find their exact representatives in the red, loose, arenaceo-argillaceous base of the volcanic breccia of Bombay, with its white specks and spots corresponding to the felspar, and its fragments of other rocks, all of which seem merely to want general consolidation and crystallisation to make the whole mass identical with the porphyry from Jiddah.

In this series of trappean effusions, masses of heliotrope and jasper appear not to be uncommon. A large block of the former was met with in tunnelling for the Bombay railroad through a low trappean ridge on the mainland, opposite the town of Tanna. The heliotrope of the Cambay ornaments comes from a hill near Rajcote in Kattywar, and at the village of Tullajah, in the same province, which is about twenty miles south of Gogah, there is a hill, composed of basalt below, laterite above, and on the top of all, a rock "like a large mass of bloodstone" (Fulljames). The heliotrope and jasper of the trappean effusions generally appear to me to be derived from fragments or masses of sedimentary rock with which the igneous ones have come in contact, or have enveloped when in a semi-fluid or incandescent state.

There are still more recent traces of volcanic outbursts in Cutch and India, but it will be more convenient to allude to these hereafter.*

XI.

Miocene and Pliocene Formations.

Hitherto we have been viewing the geological formations of different epochs in India in detached masses and tracts, without much reference to their continuity, and none at all as to the parts which were deposited in deep or shallow water, or to the deposits of lakes, rivers, or estuaries, which may have been contemporaneous with these formations; nor, in the present state of our knowledge, is it possible to do otherwise: at the same time it must be obvious, that however much their minera-

* It is to the trappean effusions which come under the head of "Volcanic Breccia" here, that the great irregularity of the land in the vicinity of the Island of Bombay may be attributed, as well as the existence above the sea of Bombay itself, and probably the greater part of Salsette; for not only does it form the back-bone of the latter, whose culminating point is 1,551 feet above the sea, but, both in Salsette and Bombay, the preceding trappitic and basaltic tracts lie about it in a comparatively fragmentary state, suspended in and supported upon it in different places, like the crust of metal melted from below.

logical characters may aid in the commencement of this investigation, nothing but an acquaintance with their organic remains in the end can enable us to determine with accuracy the boundaries and depths of the seas, lakes, rivers, or estuaries in which they were respectively deposited; or to place them in that part of the geological series to which they properly belong.

With the formations, however, which we are now about to consider, the matter is somewhat different; for their modern and fresh appearance, together with their comparatively undisturbed and unaltered state, will enable us to recognize and trace them, as a group, almost wherever they exist, without the presence of fossils; but when we come to separate these, also, according to their geological ages, the same impossibility of doing so without an acquaintance with their respective organic remains will be experienced, as in the classification of the formations which have preceded them.

Unfortunately with the miocene and pliocene, as with the older formations in India, very few of their fossils have been described; and while this arises from scarcity in the latter, it, perhaps, happens somewhat from their abundance in the former, which, with their recent appearance renders them so much like the shells now on the sea shore, that making a collection or record of them seems uncalled for. And this impression is likely to continue so long as we remain unacquainted with the great thickness of the strata in which they may have been imbedded, and the great and extensive changes which the earth's surface must have undergone since the most recent of them were deposited; but when this becomes known to us and their antiquity is thus made apparent, the many hundreds of species including whole genera, which must have become extinct during the time that has been required for their formation, points out to us the necessity of making the collections of their organic remains for determining their relative ages, which before seemed so unimportant. Indeed, it matters little about the freshness of shells, or their resemblance to species of the present day; a knowledge of those which actually exist on the coast that is bordered by these formations is as indispensable as that of those which exist in them in a state of fossilisation, when we come to determine the geological age of the latter. Collections, therefore, of shells and fossils of all localities, however common and apparently insignificant, are as necessary, in a geological point of view, as the most uncommon and curious of the oldest strata on the surface of the globe.

With this short introduction to the miocene and pliocene formations, which have been placed together, at present, for want of data to divide them satisfactorily, let us endeavour, by the aid of the scanty knowledge we possess of their fossils, their mineralogical characters, position,

and resemblanees, to draw parallels between their different deposits in different loealities, and thus, by establishing their contemporaneousness, group them and plaee them provisionally in the divisions of the geologieal series to whieh they appear to belong. In doing whieh, in the present state of our knowledge, it will be neeessary to go beyond the preseribed limits of the traet proposed for eonsideration, and to extend our observations, for eomparison, to these formations on the western side of the Indus and the shores of Arabia whieh are nearest to Western India.

Mioeene Formation.

Solid, coarse, shelly and coralline Limestone. Oyster-beds. Calcareous, argillaceous, quartzose, or sandy Conglomerates. Lower Blue Clay. Ossiferous Conglomerates.

In the southern part of Cuteh, the western part of Kattywar, and the South-east Coast of Arabia, where there have been no rivers of any consequence to interrupt, by their transported matter, the eontinued deposit of the marine exuviæ and rolled detritus of these loealities, the mioeene formation is mueh the same. Thus, in Cuteh it is stated by Grant to consist of a hard argillaeeous grit, interspersed with fossil shells; at the village of Soomrow, it is a "hard, eompaet, ealeareous rock, full of shells, and burnt for lime; and below this roek is a eoralline limestone"; the former eontains oysters near Eyeraio. These deposits "abut against the nummulitie beds"; but their thieknes is not mentioned.

I am also informed by Lieutenant Constable, I. N., who has just been engaged in surveying the Western Coast of Kattywar, that the whole of this coast is eliffless, and raised but a few feet above the level of the sea, whieh (by the specimens) throughout breaks upon a compact, gritty limestone of a yellowish eolour, raised here and there, a little inland, into mounds and hills, varying in height from 50 to 100 feet; on the top of one of these is a bed of oysters impaeted in the rock. From the specimens of this limestone which Lieutenant Constable kindly brought me, with eareful descriptions of the places from which they were taken, it evidently possesses the same eharaeters as the compact calcareous roek of the mioeene deposits on the South-eastern Coast of Arabia, and, therefore, is probably identieal in formation with it and that of Cutch. But it is only on the eoast of Arabia that I have had a good view of this formation, from whieh the following section, from above downwards, was earefully taken:—

	Ft.
Compact, coarse, shelly limestone, of a white colour, argillaceous	20
Compact, coarse limestone, of a reddish-white colour, chiefly composed of gravel from the older limestone of the neighbourhood, in an argillaceo-calcareous cement	7

	Ft.
Compact, coarse, shelly and coralline limestone, of a greenish, reddish-white colour, argillaceous; (bivalves and ostreæ)	6
A bed of large, thick oyster shells, in a coarse, compact limestone cement..	1½
Large, rounded, white limestone pebbles, in a compact, coarse limestone cement	2½
Coarse, compact limestone, of a smoky-brown colour, containing more or less of the neighbouring rocks in the state of rounded gravel; *remarkable for its cragginess where exposed to the action of the waves*	10½

This formation rests on the older limestone or igneous rocks of the locality, and constitutes the inferior two-thirds of a small cliff, which is continuous for many miles along the middle of the South-east Coast of Arabia, resting on the base of the scarped table-land which here slopes into the sea. Its strata dip slightly towards the latter, and throughout it is capped by the pliocene formation, which will hereafter be described.

The few fossils which I obtained from it belong chiefly to the family *Ostracea*, and they closely resemble those in Tab. xxv. of "Grant's Geology of Cutch." But near the village of Takah, in the upper part of the cliff, probably in the upper stratum of the above section, *Orbitolites*, H. J. C. and *Orbitoides* abound. This, when I was writing a geological sketch of the coast, appeared to be a great anomaly, for I had thought, from seeing these fossils so frequently associated with nummulites, that this deposit must be a part of the eocene formation, which in some way or other had interrupted the continuation of the cliff; yet the same parallelism and lines of stratification of the latter being equally continuous at this as at any other part, and the brown limestone rock underlying all, as usual, though the cliff (about 100 feet high) had fallen forward in great rectangular masses into the sea, left me still in doubt as to the soundness of the conjecture. Now, however, this no longer exists, for specimens of the formation, brought from the coast of Kattywar by Lieutenant Constable, also abound in *Orbiculina*, Lamarck. This, again, throws a doubt over the nature of the formation from which the specimens of limestone in the Rajpeepla Hills, sent me by Major Fulljames, came, and which I have before set down provisionally as part of the Nummulitic Series from their containing *Orbitoides;* but the whole rock bears such a striking resemblance to the miocene formation, that it now seems to me more probable that it, also, should belong to this rather than to the Nummulitic Series. Lastly, the occurrence of numbers of *Orbitolites* in another form of this tertiary deposit on the southern part of the Malabar Coast, which will presently be mentioned, sets the question at rest in my own mind, respecting the formation to which the stratum on the Arabian coast containing these fossils belongs, viz. to the miocene, and not to the nummulitic deposits.

The extreme cragginess of the lowest stratum of this series, where it has been exposed to the action of the waves, characterizes it not only

on the South-east Coast of Arabia, but on that of Kattywar, and, apparently, even in the Laccadive Islands, judging from rock-specimens of the latter which were presented to the Society by Captain Moresby, who surveyed them. It is difficult to account for this peculiar craggi-ness, unless it be owing to the more perishable nature of the portions of the older limestone rocks (which here and there form a great part of this deposit) yielding to the fretting and dissolving action of the waves, and thus leaving the cement which held them together in the peculiar form mentioned. But to whatever cause it is to be attributed, the rugged appearance of this rock, where exposed to the waves, is very striking. Its geological age, probably, as well as its composition, induces this peculiarity.

For descriptions of the fossils illustrating this formation in Grant's "Geology of Cutch," see *antè*, p. 453, *et seq.* and pls. xix. and xx.

*Lower Blue Clay.**

Contemporaneous and parallel with the foregoing calcareous formations is a blue clay, which appears to exist throughout the Western Coast of India, from Kurrachee to Cape Comorin, but chiefly in the neighbourhood of bays and inlets into which rivers have long been discharging themselves.

The following table will exhibit this better, perhaps, than separate descriptions of this deposit and its accompaniments, at the different places therein mentioned :—

Kurrachee.	Ft.	*Cutch.*	*Cambay.*	Ft.	*Travancore.*	Ft.
Blue clay, with lignite and septaria.	60	Blue clay with lignite; and "olive brown earth with pieces of amber or mineral resin."	Blue clay, with septaria and lignite ..	229	Blue clay	4
Yellow clays, sand, and conglomerates	24		(Bore at Gogah, Fulljames.)		Lignite; and mineral resin in olive-brown earth	18
Blue clay	74	Yellow marl, with lignite.			Sandy blue clay....	3
(Bore at Ghizree, Major Turner.)		(Near Baboa Hill, Grant.)			Slabs of gritty argillaceous limestone, of a bluish-green colour, containing orbitolites, &c. with rubbly matter above and below, abounding in tertiary fossils.	

* This clay has been called "lower," in contradistinction to a more modern deposit of the same kind, which will hereafter come under our consideration.

Having thus shown that the existence of this clay is general on the Western Coast of India and in Sinde, we have next to point out its contemporaneousness with the coarse limestone of Cutch, Kattywar, and Arabia, which may be inferred from the following facts: *1st.*—That, like the latter, it is immediately overlaid at Kurrachee and on the coast of Travancore by the pliocene deposits which will be presently described, while, on the other hand, it forms the lowest part of the cliffs of Travancore, which probably rest on the metamorphic or granitic rocks of that locality. *2nd.*—Near the hill called Baboa, in the western part of Cutch, which is within ten miles of the eastern mouth of the Indus, it, with the yellow marl beneath, lies immediately on the nummulitic limestone, and is again immediately overlain by the same conglomerates, apparently, which are stated by Grant to overlie the calcareous parallel of this formation at the village of Soomrow, twenty-four miles further to the south. The difference in the nature of the deposits in these two places having probably arisen from the lesser distance of Soomrow from the sea, and its much greater distance from the Indus, than the neighbourhood of Baboa hill. *3rd.*—On the coast of Travancore the blue, argillaceous, gritty limestone, with the rubbly calcareous material on each side of it, forms the base of the blue clay and lignite deposits, and abounds in fossils that are identical with those which illustrate the tertiary formation in Grant's "Geology of Cutch," together with *Orbitolites.* Further proof is hardly wanting to establish the identity of these two formations. But the account of the cliffs on the coast of Travancore, which General Cullen has kindly sent me, is so instructive, and so much more satisfactory than anything published on the subject, that I cannot do better than give it in his own words:—

"The first well I opened was on a laterite cliff or point, four or five miles NE. of the town of Quilon. Having observed some yellowish slabs of dolomite [argillaceous limestone?] at the base of the cliff or strand of the back-water, which there suddenly deepens to 40 feet, and, therefore, prevented my tracing it further downwards, I laid open several feet of the face of the cliff, and, still finding the dolomite slabs apparently passing under it, I then went above, for about 100 feet inland, and there sunk a large well, and met with the dolomite at the depth of about 38 feet.

"I then ascertained that the dolomite appeared everywhere to prevail below the laterite round Quilon, at a depth of about 40 feet from the surface.

"This was determined by the examination of wells in different localities, and by further sinking several which had not been carried down to that depth.

"I think there was a loose rubbly bed or stratum, of exactly the same

composition as the compact limestone, both above and below the slabs, and in which the greater number of the organic remains were found; but the limestone itself (though extremely hard and tough) also contained numerous specimens, in the most perfect state of preservation. The limestone is of a bluish-grey inside, but externally, where exposed to the weather, of a dull yellowish colour.

"The laterite and lignite cliffs of Varkalay, which are also near Quilon, that is about twelve or fourteen miles south, extend along the coast, about six miles, varying in altitude from 40 to 60 feet. Below the laterite is a series of beds of very beautifully variegated coloured sands and clays, and below them again, the carbonaceous clays or shales and lignites. At the north end of the cliffs, where they are only 80 feet high, the lignite bed is level with the beach; but to the south, where the cliffs attain an altitude of 140 feet, there appear to be three or four successive deposits of lignite, each of which is from 4 to 6 or 8 feet thick. To ascertain, also, if this lignite bed extended inland, I sunk a well 20 feet in diameter, at a distance of about 100 yards from the cliff, and, after passing through 22 feet of laterite only (because the well was here sunk in a hollow), came to the lignite clays. I then sunk a small well, about 5 feet in diameter, on one side of the large one, to determine the thickness of the lignite bed, which was penetrated after 7 feet, meeting then with a bed of loose, white sand, from which the water immediately sprung up so rapidly as to oblige the people to leave off working. I have not found any traces of organic remains in these cliffs, nor any traces of limestone. The carbonaceous lignite beds abound with resin and iron pyrites (white), both, in lumps of considerable size. I have a lump of the resin 10 inches in diameter.

"The variegated coloured sands that I have spoken of as lying between the laterite and lignite beds, are exceedingly beautiful—at least fifteen different and perfectly distinct tints. It has strongly reminded me of what I have often heard, but never seen, except in geological drawings, viz. the strata of Alum Bay, in the Isle of Wight.

"Plumbago and graphite, in small thin scales, abound in the gneiss and granite both of Travancore and Tinnevelly, and of course also in the laterite; sometimes in the latter in great profusion."

These observations furnish us with two important facts, of which one has been mentioned, viz. the existence of tertiary fossils (miocene) below the blue clay and lignite; which is also pointed out in another part of General Cullen's letter, and further confirmed by the identity of several specimens of a small collection which he kindly sent me from these beds, with the tertiary shells of Cutch figured by Sowerby in Grant's geology of that province. The specimens of the limestone, too, which General Cullen formerly presented to the Society through

Dr. Buist, not only bear the colour of the clay, but, with its imbedded tertiary shells, also contain portions of lignite, indicating its intimate connection with it. The other fact is, that this limestone, clay, and lignite, underlie the lateritic deposits. General Cullen is also of opinion that the laterite consists of *débris* of the older rocks of the neighbourhood; and the whole, as before stated, probably rests on the granitic and metamorphic rocks of the coast of Travancore, for there appears to be no other in this part of India,—at all events inland.

On the other side of the Ghâts, however, the matter is different, for General Cullen states:—

"On the Tinnevelly side are also granite and gneiss, but, in the low country, crystalline limestones and sandstones, as well as others of the above rocks towards the sea coast, containing organic remains." This is worth remembering, because the lateritic deposits of the Coromandel Coast will probably be found to have been formed as much from the *débris* of their neighbouring rocks as the lateritic deposits of the Malabar Coast have been formed from the rocks in their vicinity.

The following is a condensed section of two bores on the Coromandel Coast, made at Madras in October and November 1832 (Newbold):—

	Ft.
Sand and clay alternating	13
Black clay	20
Blue arenaceo-calcareous clay	12½
Granitic gravel	10
Granite	——

The presumptive evidence, then (when we remember the thickness of the lateritic deposits overlying the blue clay on the coast of Travancore), that the lateritic conglomerate forming the low undulating ground called the "Red Hills," which run parallel with the coast north of Madras, and the "Red Hills" which are in a similar position a short distance inland from Pondicherry, has been derived from similar sources, and formed in a similar way, is very great; but to the consideration of this we shall come by-and-bye. Let us now return for a few moments to the blue clay, which, by the above section, would appear to exist on the Eastern as well as on the Western Coast of India.

I have already cited reasons for considering the lower blue clay contemporaneous in deposit with the coarse calcareous beds of Arabia, Cutch, and Kattywar; and the identity between the deposits of this clay at the different places mentioned in the table, p. 745, seems, with its position, &c. to be established by the following facts, viz. that at Kurrachee it contains lignite and septaria, also capsules of chara (five-striated, similar to that now growing in the tanks of Bombay); in Cutch, lignite and mineral resin; at Gogah in Cambay, septaria; and on the

coast of Travancore, lignite and mineral resin;—while on the Coromandel Coast, the similarity of the blue clay at Madras, in relative position and general characters, to that on the coast of Travancore, although it appears to be unaccompanied by lignite and limestone, yet seems sufficient in itself to establish also their identity.*

* To those who have read both editions of the foregoing "Memoir" on the Geology of the South-east Coast of Arabia, the necessity of grouping the strata under the head of Miocene in the first edition with the Eocene in the second, will have been obvious; at the same time it will be seen, that if this has been done on the coast of Arabia it must be done on the western coast of India, for the grounds on which a similar series was established on the latter were based upon its assumed existence on the former.

That this should be the case receives further confirmation from the observations of the authors of the "Fossiles du Groupe Nummulitique de l'Inde," p. 358, who, in commenting on this part of my "Summary," observe, respecting the Miocene Group:—L'ensemble des formes ne prouve pas qu'ils appartiennent à cette période, et jusqu'à une démonstration complète, nous les regarderons comme faisant partie de la formation inférieure. * * * Nous sommes d'autant plus confirmé dans cette conclusion, que nous avons observé des Nummulites dans les échantillons d'espèces placées, par M. Grant comme par M. Carter, dans les couches de Cutch qui n'en referment pas (*Ostrea vesicularis, Natica angulifera, Solarium affine, Voluta jugosa, Terebellum obtusum, etc.*). Nous continuons par conséquent à ne commencer ici la formation tertiaire moyenne qu'avec les couches inférieures a ossements de grands mammifères.—We shall now do the same, but before making this change let us see what additional information respecting these formations on the western coast of India has been obtained since my "Summary" was compiled.

In the first place, it will have been seen by the foot-note, p. 696, *et seq.*, that the supposed nummulitic limestone from the neighbourhood of Broach on the river Nerbudda is undoubtedly of the Eocene era.

Secondly, the numbers and form of the different species of *Cerithia* in the limestone from "Bate Island" at the north-western extremity of Kattywar also unmistakeably prove that this is of the same period; though the deposit was littoral, for it is not only arenaceous and argillaceous, but there is much fossilized wood among the shells. Further down on the outer coast of this peninsula is the compact limestone made known to me through specimens brought by Lieutenant Constable, I. N., which, in addition to the characteristic *Strombus* (*S. Fortisi*, Al. Brong.? Foss. Num. de l'Inde, pl. xxx. fig. 17) of these formations on this coast, and other shells of Eocene form, is richly charged with *Orbitolites*, Lamarck, in which it resembles the orbitoliferous Eocene rock close to Ras Sajar on the south-east coast of Arabia (p. 599, *antè*). Here however, there is but one species, which in its largest size is 8-12ths inch in diameter and about 1-40th inch thick at the circumference; the centre being a little thinner chiefly because the cells are smaller, but the whole appears to be composed of a horizontal inclined plane twisting round a vertical axis, and thus would resemble a deep-cut screw so compressed longitudinally that the whorls were made to touch each other; but with the uppermost and undermost layers united at the margin and enclosing all the rest like the last whorl of a nummulite; indeed this spire is sometimes twisted round a central cell too, like that of a nummulite. The layers thus arranged are composed of lines of cells increasing slightly in size with their distance from the centre, from which they take a spiral course to terminate at the circumference. In this structure it will be seen that they resemble *Orbitolites Malabarica*, H. J. C. (Ann. and Mag. Nat. Hist. v. ii. p. 425—1853), of the blue, clayey, argillaceous limestone of the coast of Travancore, but the cells are much smaller, and the structure throughout finer and more compact, so that they more nearly approach *Cyclolina*; in the centre of which as well as in *Orbitolites*, Lamarck, I have seen the same spiral arrangement.—There can be no difficulty then in assigning this rock to the Eocene period.

Lastly comes the argillaceous limestone of the Malabar Coast, not only abundantly charged with the orbitolite just mentioned, but there again in company with *Strombus Fortisi*, together with *Cerithium rude, Ranella Bufo, Cassis sculpta, Voluta jugosa, Conus catenulatus*, and *C. marginatus* (Grant, Geol. Cutch, Tert. Foss.); also *Natica, Turbo, Pleurotoma, Fascicolaria, Murex, Cancellaria, Ancillaria*, and *Cyprea*, all (new species?) closely allied in form to the figured shells of the Eocene period. The orbitolite differs very little, except in size, from *Orbiculina angulata*, Lam. (Encyclop. Méthodique, pl. 468, fig. 3), from which I infer that the latter should also be included among *Orbitolites*, Lamarck.—There can be no objection, therefore, to considering this formation a part of the Eocene deposits, and we have now only left the lower blue clay, of which the foregoing limestone and shells being only a part, this, as a matter of course throughout the western coast of India, falls into the same category.

Not only is lignite seen in the blue clay of Travancore, but portions of it also in the argillaceous limestone, as we have seen fossil wood among the shells of the eocene limestone of "Bate Island." Gyrogonites, or seeds of Characeæ, abound in the blue clay of Kurrachee with lignite; and "Charoideæ," we find, from Captain Vicary's statements, partly characterize the upper division of his nummulitic deposits in Sinde. Gyrogonites are common in the Parisian strata, which again are equivalent to the London clay, in which are found nummulites. So that everything tends to the view taken of these formations by the authors of the Foss. Num. de l'Inde, viz. that they should be included in the Eocene period and the next division commenced from below with the Ossiferous Conglomerates.

The question now, however, which present itself is, what are we to do with the Rutnagherry deposits, which underlie laterite, and are identical, in containing similar lignite and resin, together with blue clay,—with the deposits on the coast of Travancore, now evidently belonging to the eocene era? This seems to me not to require a moment's consideration, inasmuch as the identity in the absence of characteristic organic remains in the latter is sufficient to combine the two, particularly when viewed with relation to the lacustrine strata of the island of Bombay, which from containing the remains of batrachian reptiles (viz. frogs), whose first appearance in a fossil state, according to D'Orbigny, did not take place until towards the middle of the tertiary period or upper part of the Parisian series, brings all these formations on the western coast of India into the Eocene group of Sir Charles Lyell.

Does not the capping of these deposits with black basalt at Bombay, and with "genuine laterite" (that is, laterite which contains nothing but what might come from a trappean effusion), which this is at Rutnagherry, show, that one is but another form of the other; more especially when we see a part of the top of the basalt at Bombay, close to Worlee Flagstaff, passing into laterite; and does not the shining, coaly state of the lignite in the strata at the former site, compared with its dull earthy black aspect at the latter and at Travancore, point out that the difference has been occasioned by the greater heat of the molten matter that overflowed them in Bombay, thus producing a more durable condition of the effusion here than at Rutnagherry? in short, is it not the more thoroughly molten state of the former which has enabled it to withstand the destructive agency of time, and the less molten state of the latter which has allowed it to pass into laterite?

What now, then, is to become of our Intertrappean Lacustrine Formation of the Deccan? The basalt under which it lies in the Gwailgurh Hills being, according to Voysey, the same as that of the "Pouce" in the Mauritius, is the brown old basaltic effusion of the Deccan, and not the fresh, deep, black purple one of Bombay; and who, looking at the general appearance of *Unio Deccanensis*, with its thick heavy shell converted into compact material of a deep leaden hue like that of the fossils of the Jurassic Period, compared with the white *Helix* and *Lymnea* of the European Eocene, which would seem to have their types in a formation of similar age close to Cape Comorin (Specs. in Mus. Bom. As. Soc., presented by Major General Cullen), would not instantly conclude that the formations from which these fossils came could not be of the same epoch, and that the compact blue *Unio* must belong to a much older one than the white, almost pulverulent, *Helix* and *Lymnea*?

Ossiferous Conglomerate.

Of the same period as the two foregoing formations, viz. the coarse shelly limestone and the lower blue clay, appears to be the ossiferous conglomerate, which is characterised by its number of mammalian and reptilian remains, together with more or less silicified wood.

This conglomerate forms part of the capping of a little island in the Gulf of Cambay, called "Perim," which is opposite the mouth of the Nerbudda. It exists, also, in the tributaries to the upper part of the Nerbudda, and in the valley of the Nerbudda itself; also in the Godavery and Payne Gunga; in the bed of the Jumna, in the Doab; and over a great part of Upper Sinde on the western side of the Indus.

The following is a tabular view of its relative position with respect to other formations in these parts respectively:—

Perim Island.	Ft.	*Burman Ghât, Nerbudda.*	Ft.	*Godavery, near Aurungabad.*	Ft.	*Jumna, Doab.*	Ft.	*Sinde, Gauj River.*	Ft.
Yellow conglomerate, alternating with sandy clay, containing bones of mammalia and reptiles; together with silicified wood, perforated by the *Teredo*, and infiltrated with calcspar.	21	Calcareous conglomerate	42	Alluvial deposits	40	Alluvial deposits, and beds of concretionary limestone (travertin or kunkur)........	100 to 150	Clays and sandstone.	150
		Bones of mammalia and reptiles. (Spilsbury.)		Silt	3	Clay-bed, and bones of mammalia.		Upper bone-bed. ..	60
		Omer Nuddi.		Pebble-beds, containing bones of extinct elephant	4			Sandstone and many fossils..........	60
		Regur	3	Trachyte.				Lower bone-bed. Marly clays, with *Turritella* (arenaceo-calcareous rock of Kurrachee).	
		Yellow friable loam, with layers of calcareous conglomerates, containing fossil bones	30 to 80						
(Ethersey.)		(Nicolls.)		(Bradley.)		(Smith.)		(Vicary.)	

From this table, it will be observed that the ossiferous conglomerate in the Omer Nuddi, the Godavery, Jumna, and of Sinde, is covered by a great thickness of superficial deposits, and hence, from the great time required for their formation, I am inclined to place it, for the present, in the same group with the coarse shelly limestone and lower blue clay.*

At the Island of Perim, it is composed of a fine sandy, clayey base, of a yellowish colour, imbedding rounded fragments of argillaceous strata, but never any evident portions of the trappean rocks that I have seen;† and at its lower part, fragments of the skeletons of mastodons, elephants, and, indeed, species of most of the larger forms of extinct mammalia, together with those of chelonian and crocodilian reptiles. There is also a considerable quantity of silicified wood present, all the portions of which, so far as I have seen, appear to have been thoroughly perforated by the *Teredo*, and worn at the ends as if they had been long floating and washed about in water before they were deposited. Portions of the bones are also rounded by attrition.

There appears to be this difference, which it is as well to remark here, between the vegetable remains of the blue clay and those of the quartzose or gravelly conglomerates, viz. that in the former they are carbonized, and in the latter silicified.‡

* As we have now made the blue clay, &c. a part of the Eocene Formation, its contemporaneousness with the ossiferous conglomerate cannot of course be admitted; hence it will be necessary to transfer the latter to the following or Pliocene group, and to alter the heading of this to "Miocene and Pliocene Formations," where we had better leave them for the present, or until further information indicates their geological division. At the same time we cannot help noticing here, the close analogy which this change will bring about between the deposits in the lower part of the valley of the Nerbudda and those of "Upper Sinde," now that the presence of nummulitic limestone in the former has also been established; over some parts of which it is not improbable that the ossiferous conglomerate may rest "conformably" as in Sinde; thus indicating also the deep gulf which existed in the lower part of the Nerbudda as well as in the course of the Ganges and Indus during the Eocene Period.

† Dr. Malcolmson observed "trap pebbles" in it at the Island of Perim as well as in the "cornelian conglomerate," which will be mentioned directly (see page 498); but Dr. Lush expressly excepts them in the conglomerate of Perim Island and the coast of Kattywar opposite (p. 497). I cannot find a trace of trap pebbles in any of the portions of this conglomerate which are attached to the fossil bones from Perim Island, that are in the museum of the Asiatic Society of Bombay, and these are very numerous; but in the portions attached to the fossil bones from the upper part of the Nerbudda at Barman Ghât, which were presented by Captain W. T. Nicolls, trap pebbles of the kind I have called "trappite" are unmistakeable, as well as river shells belonging to species existing in the locality, but the bones themselves are, perhaps, not quite so much solidified as those of Perim Island, though far removed beyond the state of white pulverulence.

‡ "Argillized" would, perhaps, designate the state of the fossil wood in this conglomerate better, for, though compact, it yields to the knife, and breaks with a rough uneven fracture, which is quite different to the impression conveyed by the term "silicified"; while, on the other hand, the greater part of the wood in the intertrappean strata of the Island of Bombay,

Perim Island, which is situated on the Eastern Coast of Kattywar, opposite the mouth of the Nerbudda, appears to be nothing more than a disconnected portion of the mainland, from which it is separated by a deep channel, which is about 1,200 yards in width. The island is 1,300 yards long and 500 yards broad, and its highest part is 21 feet above the level of the sea. Of this portion Captain Ethersey, who surveyed it, gives the following section from above downwards :—

	Ft.	In.
"Reddish mould or rubbish	3	0
Yellow pudding-stone	1	6
Sandy clay	1	0
Dark-coloured pudding-stone	0	6
Sandy clay	4	0
Yellow pudding-stone	1	0
Sandy clay	0	6
Recent sandstone	0	6
Sandy clay	8	0
Yellow pudding-stone	1	2
	21	2"

In the lower "pudding-stone," or conglomerate, the fragments of bones and fossil wood are chiefly found.

One of the most remarkable features about this island is the depth of water that surrounds it. The channel between it and the mainland is from 180 to 360 feet deep, and on its outer or eastern side from 198 to 1,060 feet; so that since the deposits took place which form the island, they have not only been partially raised above the level of the sea, but the great subterranean shock has occurred, which produced these immense fissures, and thus isolated the part forming Perim from the mainland of Kattywar. On many parts of the latter, too, opposite Perim Island, a similar ossiferous conglomerate exists.

It was seem by Major Fulljames in several places between Gopanah Point and Gogah, as well as some distance inland, and on the road from the latter place to Rajcote by the Rev. Dr. Wilson. Major Fulljames alludes to an interruption of its continuity by trappean rocks, but does not state whether this has taken place since it was deposited. The small capping of deposits over the ossiferous conglomerate in Perim Island may be from the early elevation of this part of the formation above the level of the sea, or, if they were ever thicker, from subsequent denudation.

What river brought the materials of this conglomerate to the coast is

which have now been classed with the "lower blue clay," is, though still more or less black and carboniferous, almost entirely argillized, and for the most part sectile: so that, after all, there is not much difference between the states of the wood, in some parts at least, of these two formations.

of course unknown, but it is not unreasonable to infer, from its position opposite to, and only fifteen miles from, the mouth of the Nerbudda, which is the largest river of Western India, that it was chiefly brought down by this river; especially when we connect the existence of similar animal remains, in abundance, in the valley and tributaries of the upper part of it.

There is a slight difference, however, between the fossil bones of Perim Island and those in the upper part of the valley of the Nerbudda about Burman Ghàt and the Omer Nuddi; while a difference again exists between the latter and the mammalian bones found by Captain Nicolls at Narrainpoor near Reiley, about forty-five miles north of Burman Ghàt, which is out of the valley of the Nerbudda. Those of Perim Island are more or less brown, and their osseous structure hard and calcareous, with its cavities filled by calcspar, coloured more or less brown by iron; those of Burman Ghàt and its neighbourhood are more or less white externally, and their osseous structure not so hard, while its cavities are filled with white or colourless calcspar; and the osseous structure of the bones found at Narrainpoor, though still calcareous, has its cavities infiltrated with agate, which is so transparent in some parts, that its clearness almost surpasses that of glass. Captain Vicary has also noticed that there are two kinds of fossil bones in Sinde, for in describing an escarpment at the Rund Pass, on the Mulmaree river, he states:—

"In the *débris* at the base of the cliff, I found some fossil bones, evidently disengaged from the arenaceous rock above, as they differ greatly from the fossil bones usually found in Sinde, which for the most part owe their hardness to hydrate of iron. The bones found here are soft, and with a calcareous infiltration."—The remains of the extinct species of elephant found in the banks of the Godavery, and sent to the Society's museum by Dr. Bradley, are in the same state; but those of the Island of Perim are all hard, brown, and more compact. If we were to see fossil shells in these two conditions, we should say that the soft friable ones were deposited at a much later date than the others. Can this be the case with these two kinds of fossil bones? The great tusk of an extinct species of elephant seen by Mr. Dean in the bed of the Jumna, those by Captain Nicolls in the neighbourhood of Saugor, and those by Dr. Bradley in the Godavery, were all of the white friable kind, while the remains of tusks from the Island of Perim are almost as hard as flint. A large collection of fossil bones which was made by Major Partridge, in the neighbourhood of Sehwan, in Sinde, and which he kindly allowed me to inspect, were, in appearance, so like those of the same species found on the Island of Perim, crocodiles and mammals, that, had I not known from whence they came, I should have set them all down as Perim fossils.

I do not know of any published or private section of the Nerbudda or its tributaries, where the conglomerate containing the fossil bones is seen to rest on the rock on which it was deposited, neither does the clay in which those bones were found by Captain Smith in the bed of the Jumna appear to be the lowest of these deposits; while the conglomerate in which Dr. Bradley saw the bones of the extinct species of elephant in the banks of the Godavery rests on trachyte imbedding large crystals of glassy-felspar, and this, again, on red amygdaloid. The conglomerate of the Godavery is composed of large and small pebbles of trappean rocks, calcedony, onyx, agate, heliotrope, laterite, and obsidian (2½ inches in diameter), all of which, Dr. Bradley states, have a vitreous surface, as if they had been exposed, in the general mass, to great heat. But in Upper Sinde, viz. in the Deyrah valley, among the Murree and Boogtie hills, which form the south-eastern angle of the mountainous tracts on the western side of the Indus, near its confluence with the branch formed by the union of the other four great rivers, this conglomerate was seen by Captain Vicary to rest "conformably" on the nummulitic limestone; which may be a further proof of its contemporaneousness with the coarse shelly limestone and blue clay. Near the pass leading into the western extremity of this valley, he states, "These hills are interesting, from the vast quantity of fossil bones and fossil wood which has been entombed within them; both are scattered about in vast profusion, and many cart-loads of the bones could be collected from off an acre of ground.

"The wood bears the appearance of having been drifted and water-worn previous to fossilisation. I noticed palms and dicotyledonous trees, one of which had a structure resembling pine; some of the stems had a diameter of 2 feet, and the quantity exposed upon a small area was truly wonderful."

The same kind of formation exists on the Sewalik hills, where its extinct fauna has been magnificently illustrated by the labours and under the direction of Colonel Cautley and Dr. Falconer, but as both the Sub-Himalayan ranges and the mountainous parts of Upper and Lower Sinde are beyond the limits of geological description prescribed for this Summary, it is not desirable to allude to the ossiferous conglomerate which they present, further than it may appear necessary for establishing the geological position and relations of this formation in India.*

* The following additional information by Captain W. T. Nicolls, confirmed by specimens presented to the Asiatic Society, has been received since the above was written.—Commencing from Burman Ghàt, which is situated on the north bank of the river Nerbudda about seventy-four miles south of Saugor and fourteen from Nursingpore, the author states, that immediately below the town is a bank of conglomerate 80 feet thick by measurement; it is coarse below,

Cornelian Conglomerate.

There is still another conglomerate that is connected with the lower part of the Nerbudda, which, from the composition of the matrix, appears to be identical with that of Perim Island—I allude to the conglomerate in which the so-called "cornelian mines" are situated.

The chief of these are about forty miles inland, at the foot of the westernmost extremity of the Rajpeepla hills, close to the town of Ruttonpore, which is about four miles from the Nerbudda, on its southern side. In describing them, Dr. Copland states that the soil in which the cornelians are imbedded consists chiefly of quartz sand, reddened by iron, and a little clay. "The nodules may weigh from a few ounces to

and fines upward into a friable, sandy deposit; throughout it is more or less infiltrated with calcareous matter, but the base of the formation being concealed by detritus, its utmost extent downwards could not be determined. At the depth of 80 feet, Captain Nicolls found the cranium of an Elephant, tooth of a Horse (?), and bones of an animal larger than a camel, together with shells of univalves and bivalves now existing in the locality; viz. two species of *Unio,* one, the large, common (?), thin species of India, and the other about half the size and thicker, which Captain N. informs me has been pronounced by Mr. J. de C. Sowerby to be *U. cæruleus;* a *Cyrena,* also stated by the same authority to be *C. cor; Paludina,* and *Melania.* All these shells, though they are more or less infiltrated with calcspar where not filled by the conglomerate, are white and but barely of sufficient consistence to hold together, in fact in much the same state as the bones would be, but for their originally more compact structure. In the dry bed of a stream opposite to Burman Ghàt, on the south bank of the river, Captain N. found tusks of different Elephants, as well as their crania, and those of Hippopotamus, Buffalo and Deer; the conglomerate bank here is only 30 feet high. Further up the river on the same side, about a mile from Burman Ghàt, or a little above the Pandoo Khonds Islands, is the village of Khan Ghàt, and between this and a large Gowlee's village, a little further on upon the northern bank of the river, Captain N. found several bovine crania. About four miles and half from Burman Ghàt, still further up on the south side, is Subonee Ghàt, close to and on the eastern side of which the Omer Nuddi enters the Nerbudda, in the banks of which both Dr. Spilsbury and Captain Nicolls found many fossil bones, partly in the coarse and partly in the fine deposits of the ossiferous conglomerate. But it is beyond this again, viz. between the place last mentioned and Jubbalpoor, and between the latter and Mundela, which has been unexplored, that Captain N. considers the most interesting part of this locality, and that which will probably afford most fossil remains. The fossil bones which he sent from Narrainpoor, to which I have above alluded, come from the water-shed apparently of the Sonar which joins the Ken river, and at a point where the sandstone and limestone of Bundelkhund meet the trappean and intertrappean lacustrine limestone formations of Malwa, according to Captain Franklin's Map, see As. Research. vol. xviii.

On re-examining Captain Nicoll's fossils from Burman Ghàt, I find that there are bones in three states, viz. dark-brown, compact; grey, infiltrated with calcspar; and white, cretaceous; together with compact argillized wood, like that of Perim Island. The compact, dark-brown bones correspond with those of Perim Island, where there are also two kinds, viz. light and dark-brown, the depth of colour merely depending on the quantity of oxide of iron in the calcspar with which the Haversian canals and cavities of the cancellated structure are filled; but I have never seen any bones from Perim Island, not even the tusks of the elephants, in a cretaceous state, as they are at Burman Ghàt; perhaps, after all, it is position, &c. and not time that we are to look to for an explanation of this diversity.

two or three pounds, and lie very close to each other, but for the most part distinct—not in strata, but scattered through the mass, and in the greatest abundance." The sand and clay in which they are imbedded is stated by Malcolmson to bear an intimate resemblance to that of the ossiferous conglomerate of Perim Island. Dr. Copland, also, states, in describing the kinds of cornelians :— " I saw none of a *red* colour at the mines; some were blackish-olive, like common dark flints, others somewhat lighter; and others lighter still, with a slight milky tinge." Some nodules, on being broken, showed a mixture of quartz and agate, and others, in a crust of quartz minutely crystallized on the inner surface, contained black oxide of iron, of a powdery appearance." Hematite [heliotrope ?] chiefly of the brown and green (with red spots) varieties, Mocha stones, and jaspers of various colours, are very common."

The shafts through this bed of pebbles are about 50 feet deep. Malcolmson, contrary to what Dr. Lush has stated, observes that there are trap pebbles among the rest here, as well as in the conglomerate of Perim Island.

It requires but a short examination of these flints to see that they have chiefly come from the cavities of trappean rocks. Their agatoid structure for the most part, and the white dimpled crust of calcedony which here and there remains impressed on them, where the attrition to which they have been subjected has not been able to reach, are proofs of their having been formed in cavities of volcanic rocks; while their roundness, and the minute curvilinear lines on their surfaces, are also proofs of the great friction to which they have been exposed. At first they have very much the appearance of the chalk flints of Europe, and it is not improbable that some are from a marine formation; indeed, a section of one which I possess has an organic form in it, but this is the only instance I have met with among some hundreds, and I am not quite sure that this came from the cornelian mines, though it came from that neighbourhood. Still, as this deposit appears to have been formed by the sea on one side and the Nerbudda on the other, it is not improbable that, like other beaches of the kind, it contains specimens of all the rocks in the surrounding country.

From its distance inland, as well as from its similarity in composition to the conglomerate of Perim Island, it appears to have been an early formation, and, therefore, probably belongs to the miocene deposits.

If any inference may be drawn from the position of the cavernous trappean rock in the island of Bombay, which is more or less filled with large bullous cavities and agates, those of the cornelian mines must have come from some of the latest trappean effusions. Be this as

it may, these cavernous rocks, when exposed to the air, appear to undergo rapid disintegration. Colonel Grant mentions one place in Cutch where "the sides of the hills (of amygdaloid) are covered with heaps of rock-crystal, as if cart-loads had been purposely thrown down"; and in many parts of the great trappean district, the surface is strewed with a profusion of agatoid flints, onyx, hollow spheroids of quartz crystals, and zeolitic minerals. Do such rocks, containing these minerals, form a part of the lower or earlier trappean effusions? It would be useful to determine.*

Silicified Wood-deposit of Pondicherry.

Lastly, we have to return again to the southern part of the peninsula, to consider the nature of a silicified wood-deposit near Pondicherry, which overlies the limestone formation of that locality, already described as containing fossils referable to the lower cretaceous and upper oolitic beds. Of this wood-deposit, Newbold has given the following description :—

"A short distance inland from Pondicherry, beds of a loose ferruginous grit rise into a low range of hills, called, from the colour of the rock, the Red Hills. They run in a NNE. direction, almost parallel with that of the coast. They are about two miles in breadth, and about eight or nine in length. The deposit, probably, extends further in a southerly direction than the north bank of the Ariacoopang river, to which I traced it from the vicinity of Camlaput on the north. The locality where the silicified wood is found in greatest abundance is in the vicinity of Trivacary, about fifteen miles west of Pondicherry. Between the Red Hills and the sea extends a plain, covered with an alluvial sandy soil, and underlying it a greyish-black or dark clayey loam, resembling that of Madras, imbedding fragments of grit and recent pelagic shells. The descent from the hills towards Pondicherry is gentle, but steeper on the western flank, where the strata have been evidently stripped off, and the subjacent fossiliferous limestones denuded, leaving a shallow valley, marking the discontinuity of the strata between this point and where the beds again appear in the vicinity of Trivacary, on the opposite or western side of the valley.

* There are several circumstances now which incline me to consider this conglomerate a part of the Eocene Strata, viz. its situation in the Rajpeepla Hills, where we have found deposits of the Eocene Period to exist; its two marked colours being red and yellow like that of the Rajpeepla limestone, the former perhaps produced by trappean intrusion (see *antè*, p. 499); the fact of its having been thus intruded; conglomerate forming the lowest deposit of the Eocene Series on the opposite coast of Arabia, and having been reddened probably by the same course in the island of Masira (p. 570, foot-note); and lastly, having found an agate pebble in the Rajpeepla limestone, presented to the Asiatic Society by Major Fulljames, that bore the dimpled surface peculiar to those which come from the cavities of igneous rocks. Should this conjecture be confirmed, then this deposit must of course be classed with the Eocene Formations.

"Here they form a low broken range of hills, not rising higher than from 50 to 100 feet above the general level of the plain, having a parallel direction with the beds on the eastern side, and sloping gently towards the east. The western flank is rugged and precipitous where it meets the hornblende schiste, which flanks it to the west near the village of Trivacary. A narrow valley marks the junction line, covered with the detritus of both rocks. Here silicified trunks of trees have been imbedded in the grit in a nearly horizontal position. The stems are both straight and crooked, generally without roots or branches, though the former have been found, and the places of the insertions are frequently strongly marked on the stem. They are monocotyledonous and dicotyledonous, coniferous and non-coniferous. Dicotyledonous wood is, however, most abundant. One of the trunks I found to measure 20 feet in length, and from 1 to 2¼ feet in diameter.

"Lieutenant Warren, in the 'Asiatic Researches,' describes a trunk about 60 feet long, and from 2 to 8 feet in diameter." Another, mentioned by Mr. Kaye, was nearly 100 feet long. (Mad. Journ. vol. xii.)

"The imbedding rock is for the most part composed of angular grains of quartz, often stained with iron, and loosely cemented together by red and whitish clays passing into a conglomerate, and into a tabular and cellular rock, differing in no respect from some varieties of laterite. * * * The beds near Trivacary are shattered by vertical fissures."

Such is an abstract of the short description of this deposit given by Newbold, the silicified wood of which, like that in Upper Sinde, and, therefore, unlike that of Perim island, appears to bear no marks of the *Teredo*, although in conglomerates in all three places. That part near Pondicherry called the "Red Hills" will come under the next division of the tertiary formations, for reasons which will then appear.

It may now be reasonably asked, how comes this miocene formation to immediately overlie the Pondicherry limestone, which contains fossils of the lower greensand and upper oolitic beds? And this question can only be answered by assuming that the latter must have undergone depression since it was raised above the level of the sea. For, whether the upheaval of this limestone took place just after its last particles were deposited,—or whether it was after the deposit on it of the formations which occurred between this and the miocene one that now rests upon it, and these intervening portions became washed off as the whole mass rose to the surface, or during its depression,—still in either way the Pondicherry limestone must have begun to descend at the time the silicified wood-deposit began to accumulate upon it. Could this silicified wood-deposit, which overlies a limestone close upon, if not of the oolitic period, have been contemporaneous with that of the diamond

conglomerate overlying our Oolitic Series? for this series, too, might have undergone temporary subsidence for the reception of the latter,—that it also underwent great denudation previous to the deposit of the diamond conglomerate has already been noticed;—while Newbold observes, at the end of his description of the silicified wood-deposit of Pondicherry: "I am rather inclined to refer this to the fresh-water chariferous limestone and chert formation than to the laterite of Pondicherry."

If the silicified wood-deposit of Pondicherry be a miocene formation, then depression of the Pondicherry limestone seems necessary for its position; while, if it be a conglomerate of the oolitic period, then it and the diamond conglomerate might have been deposited just as the Oolitic Series generally was being raised above the level of the sea. In this case, the upper beds of the Oolitic Series must have previously undergone partial dislocation and fracture, at the same time that large plains must have been left intact. For, in the first instance, we have fragments of sandstone (oolitic?) in the diamond conglomerate, and then we have the diamond conglomerate capping the hills of large districts throughout, some 1,000 feet high, near Cuddapah, where, it should also be remembered, that Dr. Heyne enumerates, among the pebbles of the diamond conglomerate, those of basalt. Further and still more precise information on the subject is much needed.

Again, Newbold remarks that "the silicified wood of the Egyptian Desert closely resembles that of Pondicherry, not only petrologically, but in *gisement*"; and certainly we cannot fail to see a great resembance, when we compare the relative positions of the two, assuming, from what has been before stated, that the latter is a miocene formation.

Mr. Orlebar, who was formerly Professor of Mathematics in the Elphinstone Institution of Bombay, carefully inspected the deposits in Egypt which seem to bear directly upon this point, and the following section is compiled from his account, given in vol. ii. of the Bombay Asiatic Society's Journal:—

Sand and sandstone conglomerate, with silicified trees (drift-wood).
Yellow limestone, with nummulites in the lower part, 60 feet.
White limestone, with nummulites.

Of the sandstone he states as follows:—"The structure of this rock is very various, although its sole mineral constituent is quartz. It forms the whole of the red hill near Cairo, where it may be studied with great advantage. In some parts it is a light yellow sand, in others a hard black rock, in others a conglomerate, in another a compact white quartz rock; and frequently it has a red tinge. The brown Egyptian pebbles belong to one of its conglomerate forms.

"The well-known fossil trees lie in this sandstone, which is found overlying the yellow limestone throughout the desert."

Hence, when we remember Captain Vicary's statement, that the ossiferous conglomerate of Upper Sinde, which abounds in silicified wood, rests "conformably" on the nummulitic rocks in the Deyrah valley, and was probably a deposit of the Indus; that the ossiferous conglomerate of Perim island and Kattywar also abounds with silicified wood, and was probably a deposit at the meeting of the sea and the Nerbudda; while the silicified wood of Pondicherry appears to be of the same age, and might have been a deposit of the Cauvery,—we cannot help leaning to the view, that one and all, the Egyptian formation included, were deposited under similar circumstances, and about the same geological period. The comparative absence of shells, too, in all, should be remembered, as indicative of a detrital commotion particularly unfavourable to the existence of invertebrated animals, and just such as might be expected to exist at the union of a rapid river with a heavy sea-swell.*

Pliocence Formation.

Semi-consolidated or loose calcareous or siliceous Sands, Grits, or Conglomerates, with more or less Marine or Fresh-water Shells, according to the nature of the deposit.

In describing the "tertiary strata" of Cutch, Colonel Grant

* It might here be asked, And to what formation belong the silicified Palm-trees of Central India near Saugor (first noticed by Dr. Spry)?—In an unpublished Memorandum on these by Captain Nicolls, to whom we are indebted for so much valuable and interesting information respecting this locality, the author states, "I have seen the remains of three" there (Dr. Spry's site). The wood "is not found on the lacustrine or intertrappean limestone, which is exposed in the bed of the nulla," but "in the trap and black soil." One tree, which Captain Nicolls dug out with great care, was 31 feet long, and buried under 4 feet of trap and black soil; 20 feet were in trap, and the rest in black soil underlaid by trap, and containing more or less trap in nodules. So far as I can judge the trees appear to have been upset and burnt down by the overflow of trap in which they are now partly imbedded, and which trap is decomposing into regur or black soil. Be this as it may, it is in the black soil and trap that all this fossilized wood appears to exist, mixed, according to Captain Nicolls, with broken agates such as are not to be found in the trap or amygdaloid of the locality. Some of the root-extremities or pedestals of the trees are erect in the trap and in the black soil, and the material imbedding the roots is of a chocolate colour. Much of the palm wood is also black as jet, and the trunks are broken into fragments, which must have occurred from disturbance after fossilisation. Here then, in answer to the question with which we commenced, it appears, that the fossil-wood of Saugor belongs rather to the regur than to the lacustrine limestone, and, as silicified bones of the larger mammalia, similar to those found in the valley of the Nerbudda, are found with it at Narrainpoor, which is only a few miles distant, it seems not unreasonable to class the whole for the present with the ossiferous conglomerate, which, as before stated, is seen to contain, at Burman Ghàt, shells belonging to species of mollusca now living in the locality; but nothing at all like the shells of the "Intertrappean Lacustrine Formation."

observes :—"A calcareous grit, which soils the fingers like chalk, also occurs in patches, and contains innumerable small shells. It is used for building, and is burnt for lime; the beds are horizontal, and the surface of the country is generally covered with a fine rich soil." It is not distinctly stated whether this "calcareous grit" overlies the miocene formation just described; but on the Western Coast of Kattywar there exists a similar deposit, particularly in the neighbourhood of Porebunder, that does rest on the miocene formation.* This is a kind of freestone, in parallel, horizontal strata, which, yielding easily in the lines of the latter, afford slabs that have for a long time been imported in great quantities at Bombay for architectural purposes, under the name of "Porebunder stone." The whole deposit would appear to be but a few feet (6 ?) in thickness, but, from its uniform structure and compactness, it serves excellently for flooring and for facing buildings. In 1848 I examined portions of it, both microscopically and chemically, and found it to be composed of minute foraminiferous shells, and a few grains of quartz and hornblende; the former semi-consolidating the whole mass, by a partial solution and recrystallization of their surfaces, and, when dissolved in acid, yielding yellow ochre casts of the foraminiferous animals they formerly contained. It thus became evident that the so-called Porebunder stone was the marine type of a formation, which from the presence of gritty particles of foreign matter, might vary in impurities of this kind to such a degree that in some parts it might be a coarse conglomerate, while in others it might be wholly calcareous. Portions of this formation from the creeks of the Runn, nine miles north of Bhooj, were submitted to me for examination by the Government, to whom they were forwarded on account of their auriferous appearance. The speckled golden colour seems to be caused by the interlamination of yellow ochre with the nacreous layers of the foraminiferous shells. I state "appears," because I am not certain that this is the explanation, though I am certain that it is not gold. The foreign particles in it consist of fragments of the trappean rocks, among which may be seen those of green-earth, their usual accompaniment.

From Cutch and Kattywar let us turn our attention to the South-east Coast of Arabia, where there is a much better illustration of this formation. Here we find it plainly developed throughout, but it is only where the miocene† formation presents the continuity of cliff mentioned that its position is clearly defined. There it is seen to form the upper third of the cliff, and to consist distinctly of an elevated beach about 6 feet thick, composed of more or less conglomerate from the older rocks of the neighbourhood, which, when traced into expanded plains

* Now considered "Eocene" in both places.

† "Eocene."

between the base of the mountains and the sea, which have also undergone elevation, or over lowland parts unbacked by any mountains, becomes of greater thickness, and of greater purity. Opposite the northern extremity of the island of Masira, where the latter is the case, it presents an escarpment of about 100 feet, and, in composition, is a fac-simile of the Porebunder stone of Kattywar. I have called it, in my memoir on the geology of the Arabian coast, "Miliolitic Deposit," from the facts mentioned. It is very oolitic in structure, but any name of this kind might confound it with "Oolite," while one associating it with foraminiferous remains, tends more to connect it with the tertiary formation to which it belongs.

On the western side of the Indus, where this formation is developed to a great extent from the vast quantity of *débris* brought down by that river, it chiefly consists of sands and conglomerates, formed in a great measure from the *débris* of the nummulitic or eocene deposits, and the shells of its own period, in greater or less abundance. It should be particularly remembered, in tracing out the limits of this formation in Sinde, that it may abound in fossils from the detritus of the Nummulitic Series, which, if not examined carefully, may be mistaken for deposits of this period.

The following section from above downwards of this formation at Minora Point, which is the western extremity of the entrance to the harbour of Kurrachee, has been given by Captain Vicary :—

	Ft.
"Conglomerate	60
Sandstone	3
Oyster-bed	2 to 4
Sandstone, becoming highly calcareous, and containing innumerable *Turritellæ*.	5
Fine-grained sandstone, no fossils apparent	—"

Beneath this (I am informed by Mr. H. B. E. Frere, Commissioner in Sinde) comes the lower blue clay ; he also mentions that the hills at Jerruck, on the Indus, which are of this formation, rest on blue clay, as evidenced by a well sunk there, and that the former so covers the nummulitic rocks in Lower Sinde, that it is not until arriving north of Jerruck, which is upwards of seventy miles up the river, that they become exposed.

The Lesser Haroo range in Luss appears to be of the same formation (Sub-Apennine of D'Orbigny?), and the greater one too, perhaps, among the mud volcanoes of the same province. In a rough sketch of a scarp of this formation in Luss, made by the late Mr. John Macleod, and forwarded to the Society with specimens of its composition by Mr. Frere, its thickness is estimated at 1,000 feet. The specimens, besides being identical with the sandstone and light-coloured arenaceous

clay which superposes the lower blue clay at Kurrachee, are almost identical with those which Lieutenant Constable presented to the Society as illustrative of the same formation on the islands of the Persian Gulf.

The only place where Captain Vicary appears to allude to the lower blue clay underlying this formation is in his description of the cliff at the Runn Pass, on the Maulmaree river, which is "about 450 to 500 feet" above the latter, where he states that "an arenaceo-calcareous rock, agreeing closely with that of Kurrachee, rests at the base of the cliff on a variegated (red, white, and blue) laminated clay, apparently devoid of fossils."

In the following section, from above downwards, of the "relative position of the formations existing in Sinde," which is the upper part of that given at p. 250, there is also no mention made of this clay, though the upper blue or "black clay," which he considers a "post pliocene formation," seems to be included under "clays and sandstone":—

"Conglomerate.
Clays and sandstone.
Upper bone-bed.
Sandstone (fossils rare).
Lower bone-bed.
Coarse arenaceo-calcareous rock, with *Cytherea exoleta?* and *exarata;* Spatangi; no Nummulites."

But in his section of the cliff on the Gauj river (p. 304), which is about 400 feet in height, and as far north as Larkhana, he observes that the bone-beds are underlaid by the "Kurrachee non-nummulitic rock," which is the last member of the section just given; in this case the ossiferous conglomerates may have to be grouped with this formation, instead of the lower blue clay, as they now stand.*

Overlying the upper ossiferous conglomerate in the Gauj river is a bed of sandstone 150 feet thick, which, being the uppermost or last deposit, is probably continued on to the base of the Murree Hills, where the confluence of the Indus with the branch formed from its four great tributaries takes place.

Passing across from this to the Doab of the Ganges, between Agra and Allahabad, we find the bone-bed, according to Captain E. Smith, from 100 to 150 feet below the level of the plain through which the Jumna now runs. In Dr. Spilsbury's section of the Omer Nuddi (p. 745), the fossil bones were found 60 feet below the surface; and in the following section from above downwards, of the banks of the Godavery at Rakishbone, kindly sent me by Dr. Bradley, and to which I have

* What is here anticipated, the reader will observe, has now been done.

before alluded,—between 40 and 50 feet of fluviatile deposits above the situation of the bones :—

"Soil.

Fluviatile deposits, full of nodules of kunkur (travertin), 40 feet.

Silt laminated, 3 feet.

Large and small pebbles of trap, calcedony, onyx, agate, heliotrope, laterite, obsidian (2½ inches in diameter). All glazed with a rich brown vitreous coating, and their interior presenting the appearance of having been subjected to intense heat. The whole mass looking as if it had once been in a state of viscidity, 1 foot.

Another bed like the former, compact in the upper part, and marly below where the bones of the extinct species of elephant were found.

Below this trachyte, followed by red amygdaloid."

How much of these fluviatile deposits have taken place subsequently to the deposit of the bone-bed, and are to be given to the pliocene formations, future observation must determine. Captain Dangerfield states, that the banks of the Nerbudda between Mundlesir and Chiculdah present a fluviatile deposit of 70 feet in thickness, the upper part of which, viz. 30 to 40 feet, is light-coloured, and the lower one, from 10 to 15 feet, is of a redder hue,—the latter rests on basalt. At Hoshungabad, two wells of 70 feet each were dug in the Nerbudda conglomerate, without passing through it (Finnis) ; and at Gogah, in Kattywar, immediately opposite the mouth of this river, where the late Captain Fulljames conducted his experimental bore, the following section, which I have condensed from his detailed one* was obtained :—

	Ft.	In.
Rubble	4	0
Sandstone	45	0
Sandy clay, and sand and clay bands	66	0
Blue clay (septaria and lignite)	229	2
Blue clay	——	

We have now to turn our attention to the southern part of the peninsula, and in connection with what has been stated, we cannot help seeing the similarity in relative position that exists between the lateritic deposit with its red and white clay and variegated sands, and the lower blue clay of the coast of Travancore, and that which obtains between the pliocene deposits and lower blue clay, or its equivalents, on the northern and western shores of India and its adjoining countries. Nor can we, when we look at the following table, fail to see the great resemblance which exists between these deposits on both sides of the peninsula :—

* Journal of the Asiatic Society of Bengal, vol. vi.

Coast of Travancore.	*Bore at Madras,* 1832.	*Madras.*	*Pondicherry.*
Feet.	Feet.	Feet.	Feet.
Loose brown sandy clay soil 6	Sand and clay alternating 13	Soil.	Surface gravel 2
Lateritic deposits (iron and graphite) 14-80	Black clay 20	Red Hills. — Lateritic conglomerate, — composed of rounded pebbles of sandstone, &c. in clay 6	Loose grit, red 4
Variegated clay, and sands.	Blue sandy clay.. 12½	Yellowish tenacious clay with no pebbles.	Grit, with weathered fragments of quartz, and felspar 3
Blue clay.	Granitic gravel .. 10	(Cole.)	Red grit, with rounded pebbles of greenstone and quartz, passing in its lower portion into a variegated and yellow grit.... 5
(Maj. Genl. Cullen.)	Granite.	Blue clay ?	Variegated red and yellow grit 4
	(Newbold.)		All the beds below the gravel are interstratified with thin layers of greenish and white lithomargic clays.
			(Newbold).

I have thought it proper to place the blue clay below the lateritic conglomerate of the Red Hills, both at Madras and Pondicherry, because in the section of the bore made at the former, which is given in the table, it will be seen that black and blue clay rest on a thin bed of gravel belonging to the granite immediately below; in fact may be considered the lowest deposit, just as it probably is the lowest deposit on the Malabar Coast, where it also underlies the lateritic deposits. Newbold's section of the Red Hills at Pondicherry being only 23 feet, and not reaching down to the blue clay, and Mr. Cole, not having been able to obtain a section of the lateritic conglomerate of the Red Hills beyond 15 feet, affords us no assistance in this way.

This is all that I have to offer on the pliocene formations* which I shall not attempt to divide here, as, in the present state of our information, it is impossible. But I cannot help thinking that there are two ossiferous conglomerates, one of which, perhaps, belongs to the miocene and the other to the pliocene deposits.

Evidence of Volcanic Disturbance and Effusion subsequent to the deposit of the Eocene and Miocene and Pliocene Formations.

Commencing with Grant's "Geology of Cutch," which gains our confidence the more we examine that of the adjoining countries, it is perfectly evident, that since the deposit of the Oolitic Beds of that

* Now "Miocene and Pliocene."

province; they have undergone the elevation which has raised them to their present level; and that, during their ascent through the sea, they may or may not have been denuded of the subsequent formations which took place between the oolitic and the commencement of the miocene periods; the previous existence of these formations upon them depending on the oolitic beds having been above or below the water when they were deposited.

If the whole of the oolitic beds had been below the water during this time, and had undergone gradual, or, as it is termed, "passive" elevation, then it seems reasonable to infer that they would now have had more of these formations upon them; whereas they have only the small patch of nummulitic limestone, in the north-western part of Cutch, mentioned. If again, the whole, viz. the nummulitic, cretaceous, and oolitic beds, had undergone paroxysmal elevation together, then also the latter, in their highest parts, might have been expected to have retained at least some small portions of the nummulitic and cretaceous beds. It seems, then, reasonable to conclude, that the nummulitic and cretaceous never did rest upon the oolitic beds of Cutch, to any great extent, any more than they have rested on the oolitic beds in any part of India; and, therefore, that those of Cutch, for the most part, having been above water when the nummulitic limestone was deposited, must have descended to have received the miocene and pliocene formations which now rest upon them.*

A question, then, arises, whether the nummulitic beds in the north-western part of Cutch, and in Sinde, which rest on the oolitic beds, did not also descend with the latter at this time to receive the miocene and pliocene deposits which rest upon part of them? And to this it must be answered, that the fact of the flat-topped, isolated tracts of the Nummulitic Series, which project above the alluvial plain of the Indus, presenting no miocene or pliocene deposits on them, so far as my observation and knowledge extend, and Colonel Grant's statement that the tertiary formation "abuts" against the nummulitic limestone also in Cutch, proves one of two things—either that the part of the Nummulitic Series on which the miocene and pliocene formations now rest, never rose above the water until the latter were deposited, or that it went down partially or wholly, after the convulsion had occurred which threw up the Hala range, and isolated tracts of the alluvial plain; the intervening portions of the Nummulitic Series having at that time been more or less broken up, and taken into the formation of the miocene and pliocene deposits.

* The division of the formations originally grouped under the head of miocene in this "Summary" should here be remembered, and that Colonel Grant's tertiary which "abuts" against his nummulitic strata is also considered Eocene.

It seems plain, then, that the Nummulitic Series underwent great displacement and destruction before the deposit of the miocene and pliocene formations; and it is also plain, from the height to which the latter have been raised, that a great paroxysmal change also took place after they had been deposited; but it is not so plain that the Nummulitic Series underwent any depression previous to or during the formation of the miocene and pliocene deposits; though the descent of the oolitic beds of Cutch, close by, to receive it, would suggest this inference.

These facts, and this reasoning, then, tend to the conclusion that the Nummulitic Series of Sinde and of Cutch has undergone two successive elevations, if not a depression also, since its formation and the end of the miocene and pliocene periods.

To what degree the elevation of these formations has extended may be conceived, when the former would appear to cap the table-land of the central part of the South-east Coast of Arabia, which is 4,000 feet above the level of the sea, and the miocene and pliocene is seen capping Gibbel Ghara, at Makalla, which is 1,300 feet above it.* Sinde and Beloochistan would furnish similar facts, if they were needed; but the extremes given are only instances of the displacement of the eocene, miocene, and pliocene formations, which in a more modified degree has taken place throughout the countries mentioned.

With such disturbances, we must of course expect here and there to have volcanic effusions; but to separate these effusions into those which took place through the nummulitic limestone previous to the deposit of the miocene and pliocene formations, from those which followed the latter, necessitates, where the miocene and pliocene formations are not present, a knowledge of the differences in the mineralogical characters of the rocks effused, if there be any, which at present we do not possess; while the large tracts of basalt which we shall find overlying the miocene and pliocene deposits, as well as breaking through them in many parts, claim our attention, from the assistance they may afford in recognising effusions of the same age in India—more than those which may or may not be confined to the Nummulitic Series.†

As usual, we must return to Cutch, where Colonel Grant, under the head of "*Distinct Periods of Volcanic Eruption*," states, with reference to the tertiary deposits :—

* We must not take the former of these extremes now as an example, for it is very problematical if the nummulitic deposits do form any part of the summit of this table-land; on the contrary, it would seem that the Cretaceous Series commenced there, and that the nummulitic deposits are to be found only at the foot of the scarp of the table-land; see the foregoing "Memoir."

† This has been obtained so far as the Eocene deposits are concerned, in finding the latter, in the island of Bombay, under a fresh, purple-black basalt, subsequently broken up by amygdaloid and other volcanic effusions, and at Rutnagherry, under laterite.

"At the village of Doonee above mentioned [in the southern part of Cutch], the banks of the river present a perfectly perpendicular wall, from 15 to 20 feet high, and are composed of calcareous grit or coarse limestone, alternating with basalt, in the following order: first grit; then a horizontal bed of round pieces of basalt; and next, another stratum of the grit 15 feet in thickness; the whole being covered by the basalt forming the hills." Near the village, again, of Kerooee, is a second instance, where the banks of the river are "composed in some places of the basalt forming the Doura Range; and in others entirely of the limestone grit, which in some places overlies the basalt, but forced up into anticlinal lines, as if the igneous rock had been protruded from below; the broken state of the strata showing that it was not originally deposited in this position. The bed of the river at this place is entirely composed of basaltic columns; their horizontal sections forming a regular pavement; and large masses of the columns, occupying from 200 to 300 square yards, and being about 8 feet in height, remain, every here and there, similar to a field of corn partially reaped. The columns are very regular, generally four-sided, with smooth, even surfaces, and are composed of a hard, compact, dark-blue basalt."

In a third instance, he adds, at the end—"Further on, * * where the dikes of basalt occur [in the calcareous grit], the limestone lies in immense masses, evidently broken off at the time of the projection of the upper bed of igneous rock; being itself of subsequent formation to the lower basaltic bed of rolled masses. This is very distinctly shown at one part of the pass, and it should be mentioned that the bed of the ravine consists throughout of irregular broken basalt."

It will be remembered that Colonel Grant's "calcareous grit" forms a part of his tertiary, and of our pliocene formations.

To the superposition of basalt and travertin, which is also underlaid by basalt, in Cutch, I have already alluded (p. 726), the superficial bed of basalt being 20 feet thick, columnar, "very hard, compact, of a dark-blue colour, and smooth surface."

But it is on the South-east Coast of Arabia that the basaltic effusions of this age are best seen, where they overlie the miocene deposits on the flat belt extending from the base of the mountains to the sea. There are three of these tracts almost touching each other, midway between Ras Sharwain and Ras Makalla, with one or more cones in each, and they all form a striking contrast in colour with the white limestone of the mountains behind, and the white deposits over which they are spread. Their general flatness, rising almost imperceptibly from their well-defined borders to the cone or cones about their centres respectively, which do not appear to be above 200 feet in height, is also very remarkable. At their circumference they are reduced to large

detached blocks and loose stones, but, further in, the mass is continuous and columnar. Although they extend over an area of about 45 miles long by 10 broad, the latter being the breadth of the plain between the base of the mountains and the sea at this part of the coast, so that they occupy about 450 square miles, and I dare to say, if we could trace them under the sea, into which they have flowed, more than double this amount. Towards their south-western extremity, where the miocene formations* have been raised about 100 feet above the sea, the basalt not only covers the surface, but, having been effused subsequent to its elevation, appears in the beds of the watercourses which open upon the beach.

I have alluded to these striking effusions on the South-east Coast of Arabia for comparison, because its geology is so linked with that of Cutch, and because this coast is so near the western part of India.

Having thus established the existence of great basaltic outbursts over the miocene and pliocene formations of Cutch and Arabia, let us now see if there be any evidence of volcanic disturbance or basaltic effusions in connection with the great trappean district of India, which have also taken place since these periods.

That there have been great disturbances since the ossiferous conglomerate was deposited on the eastern side of Kattywar may be reasonably inferred from the detachment of Perim island, which is not only capped with this conglomerate, but is separated from the coast of Kattywar by a channel or chasm 240 feet deep, while on the other side it has, in one part, 1,060 feet of water. Dr. Malcolmson, too, who visited the so-called cornelian mines, on the mainland of India opposite, states, in alluding to the presence of "trap pebbles" in them, that they have been altered by the intrusion of more recent igneous rocks, which he proposed to describe in detail at a future period;† but he did not live to carry his intention into effect, having died of fever on a subsequent geological excursion in this direction.

For direct proof, however, of basaltic effusion since the deposit of the ossiferous conglomerate, it seems that we must go to the upper part of the Nerbudda, near Jubbulpore, where, according to Dr. Spilsbury, we shall find the calcareous conglomerate in one part covered by a bed of compact basalt, "conformably stratified," and "presenting a clear section" in "three hills." The hills are about 150 feet in height, and the capping of basalt, according to the section (which is given on scale) about 40 feet in thickness.

Over this, unfortunately, Prinsep has thrown the following conjectural doubt, which I do not think the expressions in inverted commas

* These are now our Eocene, capped by the Miocene and Pliocene or "Miliolitic Deposit."
† This has already been mentioned, see foot-note, p. 746.

above mentioned justify, viz.—in alluding to the basalt stated by Dr. Spilsbury to overlie the calcareous conglomerate containing the fossil bones, Prinsep states, "Unless that the breccia containing them [the bones] occurs only in exterior patches, formed of their detritus, and containing also portions of the basalt, which one or two of the specimens, whose labels are lost, seem to render probable," that is, in other words, "unless the ossiferous conglomerate *abuts* against the basalt." In opposition to which, it might be observed, that the portions to which Prinsep alludes may have been a subsequent formation of the *débris* of both basalt and conglomerate; but of course it is impossible to say who is right, Dr. Spilsbury or Mr. Prinsep; though, in making use of the facts contained in Dr. Spilsbury's communication, it seems much safer to lean to the view of one who appears to have seen the basalt overlying the conglomerate repeated in "three hills," and to have examined them on the spot with no inconsiderable attention, than to one who, at a distance, doubts the correctness of the author's observations from the examination of a hand-specimen.

Bearing upon this question is the following extract from an unpublished account of the "Fossil Sites" about Saugor, in Central India, by Captain Nicolls, of the Madras Army.

Under the head of "Narrainpoor," a village situated among sandstone hills and small tracts of trappean rocks, about seventeen miles south-east of Saugor, and about nine miles due west of Railey, another village which is just beyond the eastern border of the trappean district of Malwa, and at the south-western extremity of the extensive tract of limestone which partly overlies the sandstone of Bundelkhund, Captain Nicolls states:—"I found fossils in three spots on the surface of the regur soil. At the first spot, fragments of dicotyledonous wood, with one fragment of palm, one fragment of fossil bone, and a fossil palm (?) seed converted into tuffaceous lime. At the second spot fragments of large bones strewed on the surface of the black regur soil, and one or two fragments of fossil wood, together with irregular flat pieces of tuffaceous limestone loose upon the surface. These bones are silicified: one small specimen is contained in the limestone sent to you (which is dendritic in the specimen). In the concave end of a vertebra found here, the tuffaceous limestone is present independently of any exterior connection, and having something the appearance of nodular kunkur. I can observe no medullary canal in these fragments, the largest of which is like the head of an elephant's humerus, 14 inches broad by 11 long. The third spot is about 150 yards from the last, and here I found dicotyledonous wood only. All the wood of the above three places was in fragments not more than 7 or 8 inches long. They lie on the black regur soil, and I see nowhere else that they could have

come from but out of it. As will be observed by the map, there is sandstone in the neighbourhood of these fossils, about three quarters of a mile off. At the third spot, the under strata are remarkable, viz. about 2 feet of black soil, then 2 feet or 18 inches of concentric lamellar trap, with a hard central nodule. This trap continues for some distance of the same thinness; below it is a chalky friable white earth, the bottom of which was not seen." Again, he states of the latter:—"Half a mile from Soorkee the white chalk-like earth is seen to the depth of about 15 feet immediately below the regur soil."

These interesting facts, then, indicate—1*st*, that fossil wood and bones silicified are found together; 2*nd*, that they are in or upon a thin stratum of regur (black soil), which overlies a thin stratum of nodular or decomposing trappean rock; 3*rd*, that this trappean rock is underlaid by a white, chalky earth; 4*th*, that a tuffaceous limestone, which is dendritic, surrounds and fills some of the silicified fossils;* and 5*th*, that all this exists in the midst of sandstone and trappean hills, which, as before stated, are within nine miles of the south-western extremity of the limestone tract overlying the sandstone of Bundelkhund, the trappean hills being, in fact, the fringed out border of the trappean district of Malwa, which also rests on the sandstone of this side.

To the above evidence of trappean effusions having occurred since our pliocene formations were deposited, I have only to add a short description of the crater of Loonar, which is situated near the village of that name about seventy miles east of Aurungabad.

Throughout the whole of the great trappean district of Western India this is the only spot which has hitherto afforded any traces of a volcanic vent, and therefore we may infer, that it was probably here that the last outburst, to any great extent, took place. Of this extinct crater, Dr. Bradley has kindly furnished me with the following account:—There cannot be a doubt of the origin of the lake of Loonar. I found, in 1852, scoriaceous rocks that fully told its history. Its upper edge [which, according to Malcolmson, who has given a short account of it, is "circular or oval"] is about five miles in circumfer-

* I have examined portions of this limestone which I found in the canals of vertebræ of large animals from Narrainpoor which were presented to the Bombay Asiatic Society by Captain Nicolls, and I find it to be earthy, dendritic in the mass, more or less compact, of a whitish yellow colour, and infiltrated with agate like the bones about which it has concreted. It differs from the earthy portions of the Intertrappean Lacustrine limestone about Saugor, in being harsher to the feel, less argillaceous, less white, and not so chalky; while it more nearly approaches in general character the modern concretionary limestone called "kunkur," at the same time it is by no means identical with the latter. Perhaps it is of intermediate age between the former and the latter, while it is again modified to a certain extent, by agatoid infiltration; but all three having been formed probably in a similar manner, it would appear in vain to search for mineral characters by which the specimens of either may always be distinguished, and therefore we must trust for this to fossil remains.

ence, and the natron lake, which occupies its centre, about three. Its sides are about 500 feet above this lake, to which they slope at an angle of about 18°, and are breached by fissured chasms, in various directions, but chiefly through the northern and eastern scarps. Dikes of greenstone are plainly seen just under the temple with the cow's mouth. The lavic currents seem, principally, to have found vent at the north-east, and to have escaped through a deep narrow gorge, the sides of which are burnt and semifused by the passage of the molten rock. The stream rolled onward beyond the city now occupied by the town of Loonar, and is seen forming step-like masses, on to the bed of a deep ravine, a little to the eastward of this place.

"Viewed from a point in a line with the axis of the plateau on which the crater is formed, little elevation is apparent, but looking at it across, you become aware of a tumular-shaped rise in the undulating ground around it, which on the south presents a mound about 60 feet high, the sides of which slope at an angle of about 50°. This slight elevation does not occur from volcanic accumulation, but simply from the tumefaction occasioned by the gaseous expansion that has hurled its central parts into the air; evidence of which may be seen in the ravines, where a true section of the walls of the crater exposes the beds of which they are composed, inclining from the crater outwards. Beneath the basis of the mound, on its outer and south-eastern side, is a hillock, upon which rests a thin layer of scoria, apparently the thinning out of a lavic current."

These are the latest traces of volcanic disturbance and outburst in India which have been recorded. That the disunion of Perim Island from the coast of Kattywar, and the effusion of basalt which overlies the ossiferous conglomerate near Jubbulpore, took place at least after the formation of some of the tertiary deposits, there can be no doubt, and the active state of the crater of Loonar appears to be equally modern; but unless the dark-blue, compact, colummar basalt, overlying the tertiary formations of Cutch, and that of the great trappean district of Western India, can be identified by their sameness of mineralogical characters, —and that sameness is peculiar to a basalt of India which overlies a tertiary deposit of the same geological age as that of Cutch,—there can be no means, that I see, of distinguishing, or of separating, generally, the basalt of this age in India from the other trappean effusions.

Fortunately, we have the intertrappean lacustrine formation to assist us in this respect; and if it shall be hereafter proved that this is of the older pliocene period, as the presence of the remains of frogs in that of Bombay would seem to indicate; that this formation exists towards the summit of the isolated mountains of the Western Ghàts; and that it is never capped but by a basalt possessing peculiarities which distinguish

it from all other trappean effusions that have preceded its advent,—then we shall not only be able to identify the latter as a post-pliocene basalt, but have a strong chain of evidence to show that the great trappean district of Western India was not broken up until the last volcanic effusions had been ejected, and that the Ghàts were not elevated until the post-pliocene age.*

That the intertrappean lacustrine formation took place after the trappean effusions had begun to be poured forth is indicated by the presence, as before stated, of *scoriæ* in some parts of its strata in the island of Bombay.

As an instance of an extinct volcano in Cutch, Colonel Grant gives a description of a crater near the shores of the Runn, which is called Denodur; it is the highest hill in the country. In its north side is a large gap, and a wall of basalt apparently continues all round the top. He also adds, that all the other volcanic hills in that part appear to be similarly constructed.

Near the village of Wagé-ke-Pudda, also, is "a space of about two square miles, blown out into a flat basin, the sides being broken into fissures, with craters, ravines, and hollows, and the interior or bed of the basin interspersed with hillocks, and cones of every variety of colour,—black, red, yellow, and white,—and with patches of cinders similar to the refuse of a furnace; the whole looking as fresh as if the igneous agents were still in operation. Within the circle, also, are several small craters, or circular spaces, surrounded by walls of basalt. One more perfect than the rest is about 40 feet high, and composed of compact columnar basalt, with a talus of sand and scoriæ."

The same author also observes of this space:—"The cones and banks of loose scoriæ must be yearly washing away, and it is difficult to conceive that the walls of solid basalt forming the sides of the craters can belong to a similar period, having all the appearance and texture of very old basalt; but it is possible that a recent eruption may have taken place in the site of one of more ancient date, thus presenting a mixture of old and recent volcanic products. If it is true that basalt owes its columnar structure to its cooling slowly under a great pressure, it is impossible that these masses of columnar basalt and the loose cones of scoriæ can be contemporaneous."

Lastly, partial alterations in the level of the country in Cutch have taken place even as lately as 1819, when they were produced by an earthquake; and passive elevation still appears to be going on insensibly throughout India.

* For more recent views bearing on this subject, see foot-note, p. 744, where the infratrappean lacustrine strata of Bombay are made a part of the Eocene deposits, and the basalt shown to differ from that superposing the Intertrappean Lacustrine Formation of the Deccan.

XII.

Post-Pliocene Period.

Marine.... { *Sands and Conglomerates, with more or less Marine Shells, loosely united.*
Upper Blue Clay, with Marine and Fresh-water Remains. }
Fresh-water. *Regur.*

Marine.

The example of these formations with which I am most familiar is in the island of Bombay, where I have had an opportunity of studying them.

Here, their maximum thickness is about 20 feet, two-thirds of which is below the level of the sea at spring-tides; and from the horizontality of their surface, they appear rather to have been deposited in the sea, and afterwards raised bodily, than to have been formed by beach-accumulation, from which the sea had gradually retired.

As with the tertiary formations just described, so with these, we have a deposit of blue clay, covered with sands and sandy conglomerates.

Blue Clay.—This is a stiff, plastic deposit, of a fine uniform texture; of a brown colour above and blue below, also yellowish where it mingles with the decomposing rocks on which it may chance to rest. When pure, it does not effervesce with acids. Its maximum thickness is about 10 feet, but this of course varies with the irregularities of the surface on which it has been deposited. Towards the sea it thins out, and is there concealed by the beach, which is now in process of formation, while, further in, it is covered by the sands and shelly conglomerates of its own period. It exists throughout the island resting on the trappean rocks, or the intertrappean lacustrine formation, where the latter has been denuded.

Like most argillaceous deposits, it contains, comparatively, very few organic remains, these being chiefly confined to the overlying conglomerates, as in the tertiary formations. Here and there, however, fragments of wood occur, in greater or less number, which appear to be the stumps of mangrove trees. These are in a soft, spongy state, when first exposed, but, on drying, shrink greatly, and assume the form of hard lignite, breaking with a smooth conchoidal fracture, and presenting a shining, dark brown colour. In this state, if lighted, it burns for a short time, with a feeble flame, gives out a woody odour, and then smoulders into a white ash. This wood has for the most part been perforated by some large xylophagous animal, which has left a number of undulous tubes in it, averaging about three-quarters of an inch in diameter, and these have subsequently become thickened by the addition of more carbonate of lime to their surface, and filled with blue clay or kunkur.

A few bivalve shells, together with remnants of crab-claws and pholadine tubes, are also found in the clay, but there appears to be a strong tendency in the calcareous material to pass off by solution, and leave nothing but their impressions. Beds of oyster-shells also exist on detached blocks and large stones, on the trappean formation beneath the clay.

Nodules of concretionary carbonate of lime, called kunkur, abound in it, similar to those of the interior of India. They are more or less impure, on account of admixture of the blue clay in which they are formed, and from which they appear to derive their bluish colour. Some few portions are white and chalky, when they are entirely composed of carbonate of lime. They are more or less hard, of a compact or earthy structure, and break with a uniform dull fracture. A fragment of wood, grass, or a shell, frequently forms the nucleus of the nodule, around which the carbonate of lime accumulates by segregation, tending always to a globular form, after which the nucleus becomes absorbed, and its mould alone remains. The globular form of the nodule does not always depend on the presence of a central nucleus, as it is occasionally seen attached in this shape to the side of the organic body.

In some localities this concretionary calcareous formation is irregularly continuous, when it is called "sheet kunkur," and in Bombay lies at the bottom of the clay, imbedding more or less gravel.

There is also another formation, of the kind called "old kunkur," and this has a concretionary, botryoidal form, not unlike globular magnesian limestone; when compact, therefore, it presents on fracture a spheroidal structure, but with the interstices filled up, and each spheroid presenting a central nucleus. This kind would appear to belong to the tertiary deposits.

The kunkur formations, in Europe called travertin, are prevalent throughout India, but do not exist in the recent deposits, except in transported fragments; neither does kunkur exist on the Neilgherries (Benza).

The blue clay immediately under the surface soil at Calcutta appears to be of the same age as that of the island of Bombay. Like the latter, also, it contains logs and branches of a red wood. After a covering of 20 feet of mould, sandy clays and sand, the blue clay extends down to about the 60th foot below the surface (see section of a "bore" which was made in Fort William in 1829), when it passes into a yellow clay with kunkur; this, after the 125th foot, is followed by "grey sand" for about 45 feet, which rests on granitic gravel at 170—176 feet. The extreme thickness of these deposits, compared with the blue clay of the island of Bombay, may be explained by the former

having been brought down by a great river from a vast extent of country, and the latter by the torrents of the neighbouring mountains, which only flow during the monsoon.

The other details of this experimental bore, which appears to have been caried on till 1837, I have not seen, but Newbold states, that at 250 feet came a bed of quartzose and micaceous sand, from which, "at 350 feet, the augur brought up the lower half of the humerus of some animal of the canine species." Then came "black peat clay, imbedding black carbonized wood, between peat and lignite, and perfectly carbonised wood, resembling the coal of Assam, in rolled lumps"; the latter from a depth of 392 feet. "Lastly, two fragments of a fossil *Testudo*, and a rolled fragment of vesicular basalt, were brought up from the depth of 450 feet."

The deposits below the quartzose and micaceous sand may, perhaps, be referred to the miocene period.

Sands, Shell-Concrete, and Conglomerates.—This formation, which overlies the blue clay, occupies several square miles of the plains in the island of Bombay, and presents a horizontal surface, raised, as before stated, about 20 feet above high-water mark, at spring-tides. It is chiefly composed of yellow sand, and beds of small shells, which in some parts pass into a coarse conglomerate of gravel and rounded pebbles, formed from the *débris* of the trappean rocks of the locality.

The sands chiefly occupy the upper part, and, becoming more shelly downwards, pass into beds of shells and shell-concrete; which, again, changes to coarse conglomerate at the bottom.

The shell-concrete is sufficiently consolidated to form a rough building material, and has been a good deal quarried for this purpose; but it is only used in the construction of the meanest buildings, on account of its cheapness on the one hand, and its indurability on the other.

The shelly beds are chiefly composed of small bivalves which have lost their colours, *Cardium* and *Tellina*, with which are mixed a few univalves, *Turbo*, *Cerithium*, and *Nerita*, and here and there a large *Trochus* and *Turritella*, and a thin pearly *Placuna*;—in short, species of all the genera now to be found on the shores of the island of Bombay. Yet, if a handful of the former be taken up indiscriminately, and compared with one from the latter, a perceptible difference between them, independently of want of colour, will be seen, in the peculiar prevalence of one species over another.

These beds rest on the blue clay inland, and are covered by the present beach towards the sea. In no instance have I ever seen a trace of anything like artificial remains or human bones in them.*

* For a more particular geological description of the island of Bombay see p. 116.

At Kurrachee there is a similar series, consisting of sands and conglomerates above, with blue clays below, resting on the sands and conglomerates of the miocene period; also in the back-waters, on the Malabar Coast, near Quilon, and at Cape Comorin (General Cullen).

Freshwater.

Regur or Black Soil.—This is in some parts from 20 to 40 feet in thickness, and is considered the best cotton ground. It consists of a fine, black, argillaceous mould, which contains in its lower part nodules, and even beds of kunkur and pebbly alluvium, and presents on its surface scattered angular fragments of the neighbouring rocks, particularly fragments of chert and jasper from the intertrappean lacustrine formation, with calcedonies, fragments of quartz, geodes, agates, &c. from the trappean rocks. It exists in large tracts here and there, and seems to have been chiefly derived from the disintegration of the trappean rocks; but on this there is a difference of opinion.

Voysey and Christie give it this origin, to which Newbold is opposed. The latter objects to it on the grounds that the disintegration of the trappean rocks yields a "red" and not a "black" soil, and that the elevation of the surface of many of the tracts of regur above that of the beds of the present rivers, together with its extensive horizontality, indicate a deposit from general submergence rather than fluviatile transport. He also considered its black colour due to carbonaceous admixture, but owns that it is as difficult to point out "the origin of one as that of the other."

Here Newbold seems not to have recollected the black surface presented by the trappean rocks, which clearly proves that when their particles are thus thoroughly exposed to the action of the air, sun, and water, for a certain time, they do become black; while the disintegration of these rocks below the surface is generally red, but not always, for sometimes they pass into a grey or greenish-brown wacken. Hence, then, the red disintegrated particles beneath the surface, when equally exposed to the air by transport, might also become black. With reference to the elevated position of the regur in some parts, and the great horizontality of its tracts in others, these might be accounted for by the changes of level which have taken place since their deposit, or since the miocene era, for the lower part of the regur must, I think, belong to this period; and its horizontality may have been effected previous to its upheaval, in the same way as that of the alluvial plain of the Indus or any other great river, the streams of which, constantly varying in their position from side to side, at last leave an almost even plain.

The origin of the regur, again, seems to be answered by the following

questions:—What has become of the enormous amount of material that has been weathered and washed off the trappean effusions, among which there is now hardly a crater or a piece of scoria to be found? Where does any part of the trappean effusions overlie the regur? And from what older rocks than the trappean could the regur have been derived? Or if it could have been, or was derived from the older rocks, what, again, has become of the material arising from the disintegration of the trappean ones?

That the regur may have been partly blackened by the growth and decomposition for ages of vegetable matter in it, no one, I think, will deny; but that the last detrital formation in India, which appears to have been immediately preceded by the trappean effusions, should be chiefly derived from any other rocks, and in any other way than that which I have mentioned, seems to me incompatible with the facts at our command. Were the trappean effusions confined to a small space, the matter would be different; but when we consider that one-fourth of Hindustan Proper is now covered by a continuous sheet of trappean rocks, and that dikes and small patches exist in the greater part of the other three-fourths, all of which are inconceivably reduced from their original dimensions, the existence of large tracts of black earth throughout India seems to be as natural a consequence as the formation of older strata from an eruption or destruction of rocks in their vicinity. —Thus the miocene formations in Sinde are so made up of the fossils and *débris* of the Nummulitic Series, which immediately preceded their formation, that it becomes a matter of difficulty sometimes to say which is which.

Lastly, the facts mentioned by Captain Nicolls, viz. that at the village of Narrainpoor, in Central India, 9 miles south of Saugor, 2 feet of black soil in one place rests on 2 feet or 18 inches of nodular basalt, which, therefore, must be decomposing, show that the whole of this basalt will soon become a part of the black soil; while Dr. Adam, after having stated that this is the prevailing soil in the part of Bundelkhund over which he travelled, adds:—

"The black soil has evidently been derived from the decomposition of some of the many varieties of trap rock, most probably amygdaloid or green earth, which appear to have rested at one time over the granite in the hills of Bundelkhund. The trap rocks at Gerawah and Bisramgundj, and the globular variety of Kalinghur, may also have had a share in forming it. As I remarked before, many of the trap boulders are now in a soft state, bordering on earth, and can be reduced to powder with the greatest ease. The soil immediately around, there can be no doubt, is formed of their *débris*, and as the plain in general resembles that, we may resonably infer that it also acknowledges a similar source."

XIII.

Recent Formations.

These I need not describe; they may be seen on our beaches, and in the alluvial deposits of the rivers which form the boundaries of the tract we have had under consideration.

Theory.

As a theory of the geological formation of a country is frequently desirable for the right understanding and remembrance of the facts contained in its geological description, so I feel called upon to terminate this "Summary" with a few observations on the manner and sequence in which the different formations of India appear to have been produced. At the same time I feel that it is perfectly useless to attempt this further back than the commencement of the Oolitic Series, for it will have been seen by the foregoing pages, that there is little or nothing to assist us in theorizing respecting the formation or position of the Plutonic Rocks and Metamorphic Strata previous to this period, and that even since, our knowledge of the subsequent formations is so scanty that it hardly justifies a conjecture.

Leaving the reader, then, to supply with his imagination the state and position of the Plutonic Rocks and Metamorphic Strata previous to the commencement of the Oolitic deposits, I would suggest for his consideration—

1*st.*—That the Oolitic Series, which appears to contain the coal beds of India,* was deposited by rivers flowing from the north.

2*nd.*—That the marine beds of this series (indicated by their shelly nature), at the southern extremity of India, and in Cutch, seem to point to the outskirts of this delta, or the margin of pure salt-water, during this period.

3*rd.*—That this delta, viz. the greater part of India, was raised above the level of the sea before the Cretaceous and Nummulitic Periods commenced, while its eastern and western borders, extending to the Himalayas on one side, and in the direction of Sinde and Beloochistan on the other, still remained under water.

* It might be supposed by some, that because this coal is of the Oolitic Period, it can never beat the English coal of the Carboniferous Series out of the Indian market; but the following extract from a note which accompanied a present of a specimen of Burdwan coal to the Society, by J. Ritchie, Esq., Superintendent of the P. and O. Company's Steamers in Bombay, furnishes most satisfactory evidence to the contrary. Mr. Ritchie states :—"I consider that it will be a valuable coal for steam purposes.—At the Mint, and also at this Company's workshops in Calcutta, it has been converted into coke nearly equal to that from England, and costing considerably less." When the proposed railway, then, is completed, which is to connect the Western Coast of India with Calcutta, the coal beds of India will become still more available, for this must pass through the districts in which they appear to abound most, and to be nearest the surface.

4*th.*—That the deposits of the Cretaceous and Nummulitic Periods, which now form part of the sub-ranges of the Himalaya mountains, and the Hala range of Sinde, &c. were formed and raised above the level of the sea, leaving a gulf on each side, one in the present course of the Ganges, and the other in the course of the Indus rivers.

5*th.*—That the Miocene and Pliocene deposits were formed in these gulfs, and were also raised above the level of the sea, causing the latter to retreat almost to its present margin.

6*th.*—That the alluvia of the Ganges and Indus were deposited.

With reference to the advent of the trappean effusions, it would seem —if the coal formation resting on "secondary trap" in the Rajmahal hills should hereafter prove to be a part of the Oolitic deposits, as Dr. M'Clelland supposes, and also to have been deposit on this trap,—that the Trappean Period extended from the deposit of the Oolitic Series down to the breaking up of the Miocene and Pliocene deposits, inclusively.*

The Diamond Conglomerate would, then, have been formed after the commencement of the trappean effusions,as it rests upon the Oolitic Series.

The deposits of the Intertrappean Lacustrine Formation seem to indicate a long interval of volcanic cessation previous to the outpouring of the basalt, which overlies them in the Great Trappean District.

Note.

In the following "Provisional Table of the Igneous and Sedimentary Rocks of India" I shall not introduce the alterations proposed and suggested respectively, in the foregoing "Foot-notes," any more than I have done in the text to which they refer; it will be sufficient to indicate them again here, and leave the reader to manage this for himself. Thus, groups ix. and xi., which comprise the "Miocene and Pliocene Formations," should be joined under this designation, while all except "Ossiferous Conglomerate," which has been bracketed opposite "*Marine*," in group ix., should be transferred to the Eocene or viith group; a place for the "Intertrappean Lacustrine Formation," also in group ix., has not yet been found, since, putting aside the "Miocene and Pliocene Formations" here, particularly as they now stand, it seems not unlikely that, after all, this formation may be found to be older even than the Eocene deposits; hence, for the present, we have no choice but to leave it where it is, unless it be thought better to remove it, provisionally, to the Oolitic Series (see pp. 658 and 744).

These alterations will not affect the position of the "Trappean Effusions," which must remain as they are, though, as regards mineralogical characters, they also probably will be found to possess their respective peculiarities.

* Should this be the case, it would be very desirable to obtain characters for distinguishing the trap of the Oolitic Period from that of subsequent effusions.

PROVISIONAL TABLE OF THE IGNEOUS AND SEDIMENTARY ROCKS OF INDIA.

	XIII. RECENT.		Deposits now taking place.	
POST-TERTIARY	XII. POST-PLIOCENE	*Marine*	Sands, Shells, and Conglomerates. Upper Blue Clay. Kunkur (Travertin).	
		Fresh-water	Regur. Kunkur.	
				X. Trappean Effusions, 2nd Series.
TERTIARY	XI. PLIOCENE	*Marine*	Semi-consolidated or loose calcareous or siliceous Sands, Grits, Shells, and Conglomerates.	
		Fresh-water	River Conglomerates. Old Kunkur.	
	MIOCENE	*Marine*	Solid, coarse, shelly Limestone. Oyster-beds. Calcareous, argillaceous, quartzose or sandy Conglomerates. Lower Blue Clay. Ossiferous Conglomerate.	
		IX. *Fresh-water*	Intertrappean Lacustrine Formation.	VIII. Trappean Effusions, 1st Series.
	VII. EOCENE		Nummulitic Beds and White Marl.	
SECONDARY	VI. CRETACEOUS	*Marine*	White Limestone, Arabia and Sinde? (1,400 feet?) Upper Greensand and Gault, (Albien, D'Orbigny,) Trichinopoly and Verdachellum. Lower Greensand (Neocomien, D'Orbigny) Pondicherry.	
	V. OOLITIC	*Fresh-water*	Diamond Conglomerate? Punna Sandstone.	(Trappean Effusions?)
				Eruption of Felspathic and Hornblendic Rocks.
			Kattra Shales: *Fresh-water?* Shales. Limestone. Coal. — *Marine* Cutch. Poondicherry.	
			Tara Sandstone. (Old Red? M'Clelland.)	III.
PRIMARY	IV. CAMBRIAN AND SILURIAN (M'CLELLAND).		Transition Gneiss, with micaceous and hornblende Schistose Beds. Newer Clay Slate, with quartzose and steatitic Sandstone Beds.	
				Eruption of Felspathic Rocks.
	II. METAMORPHIC STRATA.		Gneiss. Mica Schiste. Hornblende Schiste. Clay-slate. Granular Limestone.	I. Primitive Plutonic Rocks.

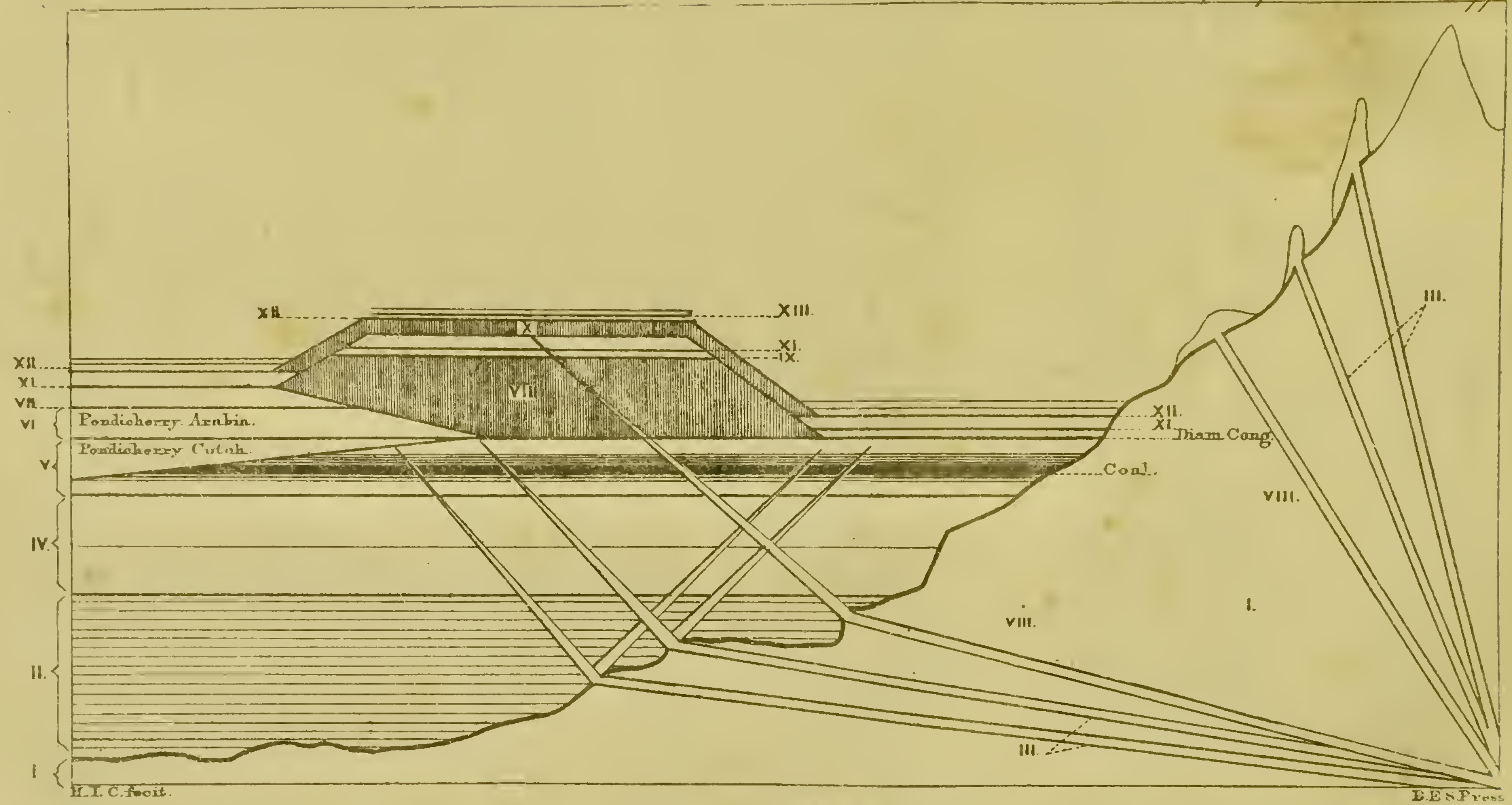

DIAGRAM.

For explanation see Table p. 776.

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* It was my intention to have given a list of the titles of these papers *in extenso*, but it would take up more room than can be afforded. I must therefore be content with giving the names of the publications only in which they are to be found respectively.

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Taylor, Capt. Meadows, H. H. Nizam's Service, Deputy Commissioner of the Western Ceded Districts.

* Mr. Fraser's paper in the Geol. Trans. Lond. 4to, New Series, Part 1 of Vol. V., I have not been able to obtain.

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